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INTERNATIONAL BAMBOO AND RATTAN ORGANIZATION

Technical Paper

Ethno-Taxonomical Classification and Potential Applications of *Oldeania alpina* (Highland Bamboo) Landraces in Ethiopia

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About the International Bamboo and Rattan Organization

The International Bamboo and Rattan Organization, INBAR, is an intergovernmental organization dedicated to the promotion of bamboo and rattan for sustainable development. For more information, please visit: www.inbar.int.

About this Working Paper

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Foreword

The drive to slow down the extraction of woody forest resources in East Africa has provided countries with the opportunity to earnestly seek alternative sources of wood and related composite materials. Bamboo is fast emerging as one of the priority alternatives under consideration. It is a versatile resource with several documented uses, such as a timber substitute; in pulp and paper as well as fiber and textile industries; as plastic composites; as food and beverage; for energy; in health; and in cosmetics. Furthermore, it has proven potential for soil erosion control, water recharge, and climate change mitigation and adaptation. Bamboo is considered to have the potential to contribute to flagship programs with a focus on small and medium-scale enterprise (SME) development to promote manufacturing, the rehabilitation of degraded landscapes, employment creation, poverty reduction, economic development, and environmental resilience. In this regard, the Government of Ethiopia considers bamboo an essential natural resource and aims to promote it for environmental conservation and commercial use. Widespread adoption of bamboo is expected to significantly contribute to Ethiopia's commitment to increase forest cover under its 10-year bamboo development strategy.

Highland bamboo (*Oldeania alpina*, Syn: *Yushania alpina*) is distinguished by a variety of morphological characteristics that are crucial for sub-classifying the species into landraces. These characteristics include culm size, color, internode length, nodal protrusions like dried aerial roots, nodal branch density, and foliar biomass. In addition to these morphological variations, communities in the growing regions use landraces for a variety of purposes based on physical strength, working property, ease of splitting or tendency/resistance to splitting, resistance to powder post beetle damage, etc.

A landrace is a genetically diverse, cultivated variety that has grown naturally in a specific eco-geographical region and has adapted to its edaphic and climatic conditions. An identifiable local name is a landrace. It is closely related to the uses, knowledge, customs, dialects, and holidays of the people who developed and are still growing it, but it lacks formal crop improvement. Typically, the term "landrace" refers to plants with vegetative reproduction, such as bamboo, that have been cultivated and propagated in a specific region for more than 60 years.

The goal of this study is to distinguish between highland bamboo landraces that could be used

for industrial applications, fencing, house construction, furniture production, weaving, livestock feed, and landscape restoration. It also identifies the need for additional genetic characterization in the event that some of the landraces have distinct identities in the scientific taxonomy and describes the growth performance of various landraces based on dendrometric parameters.

INBAR thanks the Ethiopian Forestry Development (EFD) research team for this insightful and timely study, which is pertinent for wider use and application. In addition, INBAR recognizes the assistance given by the neighborhood bamboo farmers in each of the study districts. I believe that this research work will be beneficial for developing the bamboo industry in Ethiopia by providing valuable information about the use and application of highland bamboo varieties for restoration and industrial purposes.

Ali Mchumo
Director General
International Bamboo and Rattan Organization

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Executive summary

The subtropical African nations of Burundi, Cameroon, Congo, Ethiopia, Kenya, Malawi, Rwanda, Sudan, Tanzania, Uganda, Zambia, and the Democratic Republic of the Congo are among those where the highland bamboo (*Oldeania alpina*) (K. Schum.) Stapleton (Syn: *Yushania alpina*) is naturally found and grown. *O. alpina* thrives widely and is dispersed throughout Ethiopia's highlands in the south, southwestern, central, and northwestern regions.

The goal of this study is to evaluate Ethiopia's highland bamboo landraces based on their dendrometric and morphological characteristics. The research also identifies the best landrace for wood-based industries to enable the production of high-quality finished goods, and informs landscape restoration efforts in terms of appropriate landraces in the nation's afforestation and re-forestation programs. Based on the differences in physical and morphological traits, landraces can be divided into classes (Irawan et al., 2019; Mulatu and Fetene, 2011). The naming of landraces by farmers is based on the morphological features of the culm, branching behavior, and farmers' interest in its different uses (Gebrekidan et al., 2018; Mulatu and Fetene, 2011). The four regional states of Ethiopia were included in the study, namely the Amhara Region's Awi Zone (Banja District), the West Gojjam Zone (Machakel District), the Southern Nations, Nationalities, and Peoples' Region's (SNNPR's)Gurage Zone (Gumer District), the Gamo Zone (Chencha District), the Sheka Zone (Masha District), the Sidama Region's Hula and Arbegona Districts, and the Oromia Region's Jimma Zone (Seka Chekorsa District).

The term "paramorph" describes a group of people. The need for field management in the study areas, the workability of the culms of the various highland bamboo landraces, and other technical information were all gathered through extensive field surveys. Descriptive analysis was used to process the qualitative data from observations of the color of the culm, the presence or absence of nodal protrusions or hardened nails such as arial roots, the density of the branches, and data from focus group discussions (FGDs) and key informant surveys (KISs). The quantitative measurements taken on diameter at breast height (DBH), height, number of nodes, internode length, etc., from the field were subjected to statistical software (SPSS Version 20) to identify variability among the landraces.

Approximately 24 landraces were found and are described in the study, each of which had unique morphological characteristics and historical applications. However, it was also found that landraces discovered in remote, distant locations shared morphological traits. For instance, it was discovered that the *na'a* landrace from the Chencha District shares morphological traits with the *hinkonota* from Hula, the *tifro* from Machakel, the *michi* from Masha, and the *thilla* from Arbegona. These highland bamboo landraces were noted to have prominent nodal nail-like protrusions or hardened aerial roots, dense branching habits with significant leaf biomass production, and a propensity for breaking at the nodes while splitting, a trait that can be used in various products. The *tsarzo* landrace from Chencha, on the other hand, is comparable to the *sella* from Arbegona in terms of its long internode length and strength, and it is frequently used as the skeletal foundation when constructing traditional bamboo houses in the districts. *Lala* and *lodo* from Chencha, *hinkonokita* from Hula, *midasho* and *ganticha* from Arbegona, *shimiti* and *demamu* from Masha, and *agade* from Gumer District, Guraghe Zone, are among the landraces that are frequently grown for the market. We advise that landraces such as*lala*, *lodo*, *tsarzo*, *hinkonokita*, *sella*, *midasho*, *ganticha*, *shimiti*, *demamu*, *tikuro*, and *agade* be widely promoted to new areas in the highlands for wood-based industries to enable the production of quality end products based on the preferences of knowledgeable local bamboo processors.

Finally, bamboo landraces with their unique geographic site factors can be propagated in climates that are similar in order to restore landscapes on sloped mountains, along riverbanks, and in gullies. In order to confirm the presence or absence of genetic differences among landraces from different locations, it has been suggested that genetic variability should be checked through gene-sequencing procedures to supplement the findings. As a result, the research suggests planting at least three different regions with landraces from different growing regions to test their growth performance and to use the same strategy for genetic conservation. These samples can also be used to test hypotheses about genetic variability.

1. Introduction

Highland bamboo *(Oldeania alpina)* (K. Schum.) Stapleton (Syn: *Yushania alpina*) is naturally distributed and cultivated in subtropical Africa, specifically in Burundi, Cameroon, Congo, Ethiopia, Kenya, Malawi, Rwanda, Sudan, Tanzania, Uganda, Zambia, and the Democratic Republic of Congo. Highland bamboo is perennial and has short rhizomes, with erect and woody culms about 2.0–19.5 m long and 5.0–12.5 cm in diameter (UNIDO, 2009). Culm internodes are smooth, cylindrical, and tapering (terete) with thick walls; nodes have many lateral branches in an irregular line and are sub-equal in number. Culm sheaths at the base are smooth and hairless, or have bristles (glabrous) with red hair sat the upper end, resembling earlobes (auriculate), or have bristles (setose) on the shoulders (Yigardu and Masresha, 2011; Hedberg and Edwards, 1995). The culm-sheath blade is linear and acute. The leaf-blade base has a short petiole-like connection to the sheath. Leaf-blades are lanceolate, 5–20 cm long and 6–15 mm wide. The leaf-blade venation is arranged with distinct cross veins, while the leaf-blade surface is glabrous with the apex attenuate and filiform (Hedberg and Edwards, 1995).

In Ethiopia, *O. alpina* grows widely and is distributed in the south, southwestern, central and northwestern highlands in an altitudinal range of between 2,200 m and 4,000 meters above sea level. *O. alpina* (highland bamboo) has variable growth characteristics (culm size and height, number of nodes, and internode length), morphological attributes (color, rhizome length, and width), and wood working properties(Mulatu, 2012;Gebrekidan and Mulatu, 2018)from natural as well as plantation cultivation. These variations in morphological and physiological traits have evolved due to adaptation to diverse geographical and edaphic conditions. Natural and artificial selection resulting from the exchange of seeds can contribute to creating different landraces (populations), whereas the migration of seeds between populations results in groups of interrelated landraces (Figure 1) (Casañas et al., 2017). Landraces can evolve through mutation, migration, recombination, and crossing with other populations; as a result of the soil, climate, and other ecological conditions of the region of cultivation; and due to the influence of humans (Zeven, 1998). It seems there are several landraces of this species.

A landrace is defined as a cultivated, genetically heterogeneous variety that has evolved in a certain eco-geographical area and adapted to the edaphic and climatic conditions (Casañas et al., 2017): “Landrace is identifiable and usually has a local name. It lacks formal crop improvement and is closely associated with the uses, knowledge, habits, dialects, and

celebrations of the people who developed and continue to grow it" (Veteläinen et al., 2008). The term "landrace" is also used for perennial crops and crops with vegetative reproduction such as bamboos, which have been cultivated and reproduced in certain areas for more than 60 years (Calvet-Mir et al., 2011).

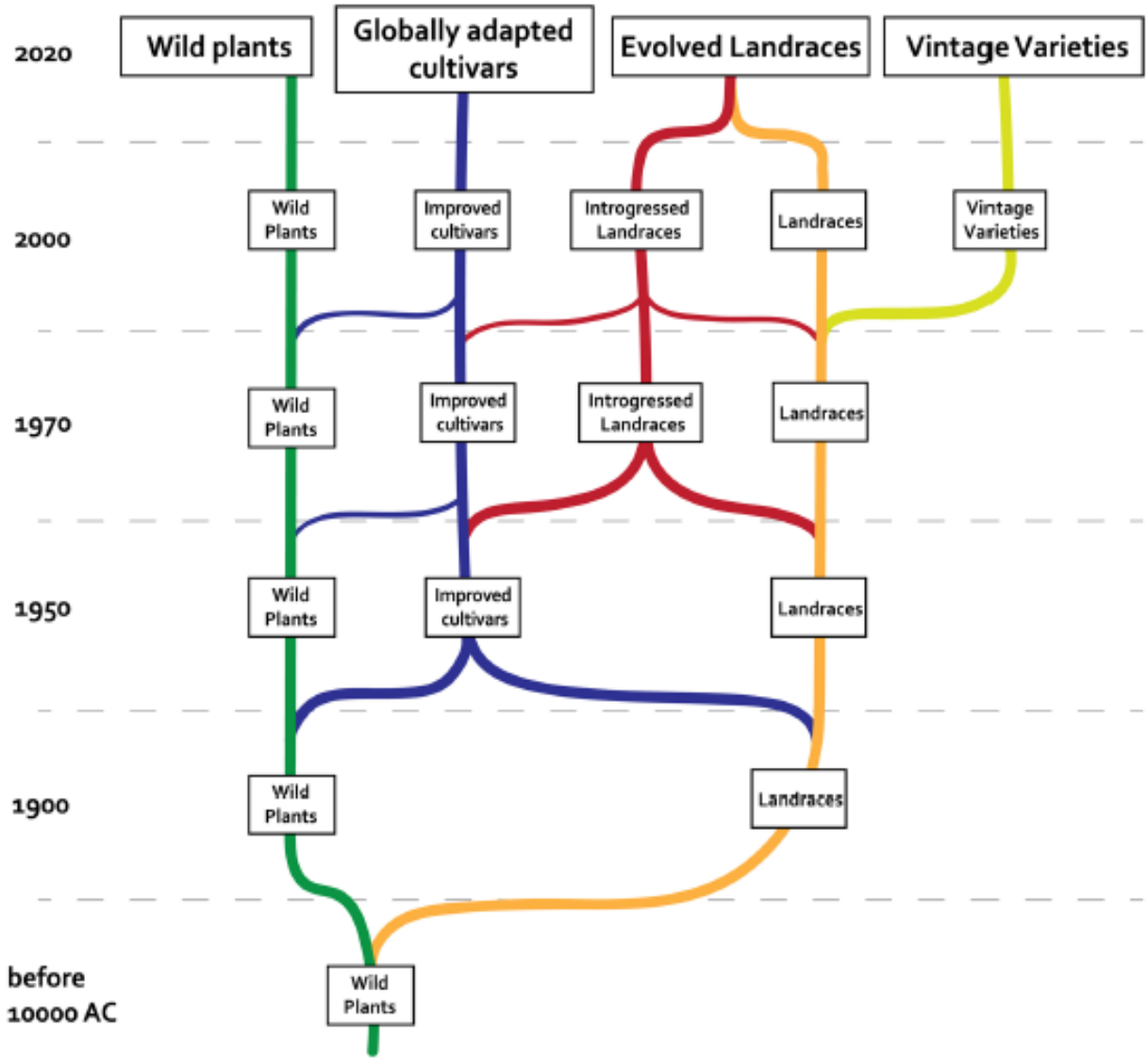

Figure 1. Timeline of historical relationships among different kinds of plant materials and prospects for the immediate future (Casañas et al., 2017). **Note**: AD in place of AC.

Landraces can be categorized into classes based on the differences in physical/morphological characteristics (Irawan et al., 2019;Mulatu and Fetene, 2011).The names of the landraces are based on the morphological features of the culm, other bamboo parts, and farmers' interests(Gebrekidan *et al.*, 2018; Mulatu and Fetene, 2011). Local people classify bamboo landraces based on the color of the culm, the internode length, the thickness of the culm, the

surface roughness of the culm, the surface area and length of the leaves, the sprouting ability, the length between nodes, the diameter of nodes, the rooting nature, the response to splitting, and the thorniness at nodes (Gebrekidan et al., 2018; Mulatu and Fetene, 2011). Adaptive genetic factors, combined with environmental factors, determine the characteristics of the young tree as it grows. For instance, clones from vigorous trees will most likely produce vigorous trees. Using clones derived from plants selected for quality means obtaining similar dimensions, properties, and growth characteristics to the mother clumps, when grown under similar conditions. It is obvious that mother plants are a keystone in growing future quality planting material. Good quality bamboos from selected landraces can be cloned for specific bamboo utilization, as the bamboo products will be affected by the culm of the landrace used.

This study focuses on assessing the number of available bamboo landraces in Ethiopia, based on their dendrometric and morphological traits, and aims to recommend the best landraces for wood-based industries, to enable the production of quality end products, and to inform and support the landscape restoration efforts with suitable landraces for the afforestation and re-forestation programs being undertaken in the country.

2. Methodology

2.1 Study sites

This study was conducted in the potential bamboo-growing areas of the highlands of four regional states of Ethiopia, these are Amhara Region: Awi Zone (Banja District) and West Gojjam Zone (Machakel District); the SNNPR: Gurage Zone (Gumer District), Gamo Zone (Chencha District), and Sheka Zone (Masha District); Sidama Region: Hula and Arbegona Districts; and Oromia region: Jimma Zone (Seka Chekorsa District). The study covered bamboo-growing districts between the altitudes of 2,300 m and 3,000m (Figure 2).

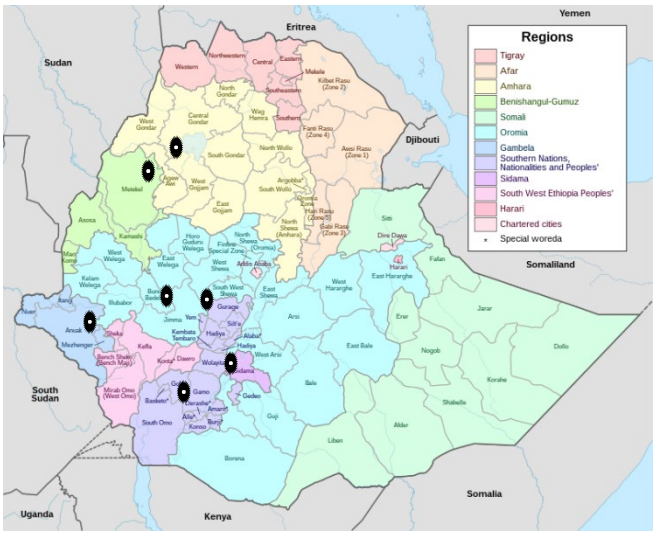

Figure 2. Map of Ethiopia with the asterisk mark indicating the regions and the seven zones where highland bamboo landraces were studied.

2.2 Data collection

2.2.1 Desk review

A review of the literature on highland bamboo landraces' diversity, morphological characteristics, growing climate, and geographic locations and utilizations was conducted, including published and unpublished reports and theses, proceedings, journal articles, and grey literature. Ecological and climate data, such as topography, temperature, altitude, rainfall, flood influence (drainage), relative humidity, latitude, and longitude collected from the INBAR and the Ethiopian Environment and Forest Research Institute (2021) study on bamboo species-site matching in Ethiopia were reviewed and adopted.

2.2.2 Field survey

Identification and ethno-characterization of landraces: Extensive field visits were conducted to collect technical information on the ethno-taxonomy, identifiable characteristics, management requirements and workability of the timber of the different highland bamboo landraces from the above specified study areas. The research team consulted with relevant stakeholders at regional, zonal and district levels to select appropriate sites within the districts to identify landraces. Visual observations were carried out across bamboo sites through Transect walks (direct field observation together with knowledgeable community members) to locate and identify landraces managed by the community. Focus group discussions and key informant interviews were also held with the communities who own and manage the bamboo areas where the identified landraces grow or are cultivated.

Highland bamboo sites with identified landraces with similar landform and management for at least the past ten years were selected for the present study. All relevant parameters for the identification of the available landraces, such as local name, DBH, height, number of nodes, internode length, spacer length (rhizome neck), culm color, features of the nodal region, presence and absence of aerial roots arising from the nodes, and culm sheath ring and shape were recorded. Moreover, data on the site structure (density within 9 m^2, number of recruited culms, DBH and height) were documented.

3. Results and discussion

3.1 Ethno-taxonomic classification of bamboo landraces

A field survey of the bamboo plantations and bamboo sites for the identification and ethno-description of bamboo landraces was conducted in the bamboo-growing highland districts of Amhara, Oromia, Sidama, and the SNNPR states of Ethiopia. The results are presented by district, and the identified landraces are described based on farmers' knowledge and expert observations on the morphological traits. Apart from the perceptions of the local people and their classification based on the use of landraces, the morphological features and quantitative characteristics, such as general appearance, size, colors of culms, presence or absence of a particular feature, for example nail-like aerial roots, etc., were also studied and described for each landrace. Bamboo growers and processors mostly distinguish between the landraces based on parameters such as culm diameter, length of internodes, culm color, protrusions on the culm node such as the aerial roots, and the splitting tendency/resistance of the culm.

3.1.1 Banja District

In the Banja District of the Amhara region, all the interviewed respondents (n = 30) stated that they are well acquainted with three types of bamboo landraces in their area, based on the culm color, namely the *tikuro* (the dark), the *qeyo* (the red), and the *zingurgur* or *zeger* (yellowish with a stripe) bamboo (Figure 3). The respondents also stated that two of the landraces are planted either in their home gardens or on the boundaries of their farms. Due to its better woodworking properties (ease of splitting and flexibility for weaving) and massive shoot production in bamboo forests, approximately 66.7% of respondents prefer *tikuro* over *qeyo.* In addition, the *tikuro* landrace has higher market demand, which enables growers to reap financial benefits when selling the culm (Table 1). The remaining 33.3% of respondents stated that they prefer *qeyo* over *tikuro* for its greater culm strength.

Table 1. Summary of the two landraces' characteristics in Banja District

***Tikuro* (dark culm) landrace**	***Qeyo* (red culm) landrace**	***Zingurgur***
• Culm has a thicker diameter • Longer internode length compared to *qeyo* • Longer culm height • Lower termite tolerance as compared to *qeyo* • Culm is deep green when young compared to *qeyo* • Has lower number of precocious nails (rudiments of aerial roots) at the nodes • Easy to split, and mostly used for weaving and basketry • Higher market demand	• Culm has a thinner diameter (*qeyo* is thinner than *tikuro* in diameter if planted on the same soil type) • Shorter internode length compared to *tikuro* • Shorter culm height compared to *tikuro* • Better termite tolerance • Culm is gray when young compared to *qeyo* • Stronger than *tikuro*, used for furniture-making, such as chairs, beds, shelves, tables, etc. • Has strong nails compared to *tikuro* (rudiments of aerial roots) at the nodes • Resistance to splitting (breaking down while splitting when it dries)	• The culms are striped • Was cultivated on only one farmland • Scanty information on processing compared to other landraces. • Good for weaving compared to *qeyo* • High production potential per unit area compared to other types of landraces

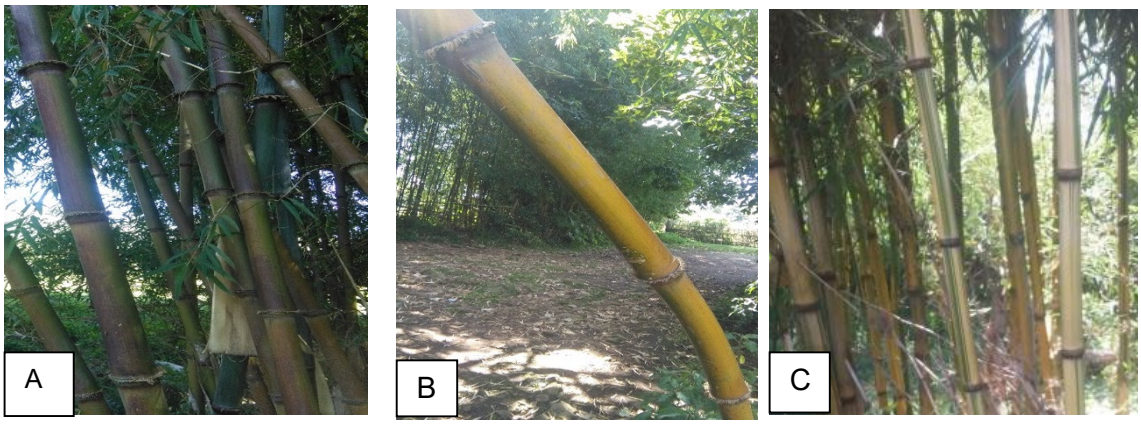

Figure 3. Landraces found in the Banja District: a) *Tikuro*; b) *Qeyo* C) *Zingurgur*

3.1.2 Machakel District

The survey indicated that two highland bamboo landraces are found in home gardens and on the borders of farmlands in the study area, namely, *tifro* and *wolele*. All respondents mentioned that they plant one or both of the landraces on their farmland and in their homegardens. Most of the households (76.70 %, n = 30) prefer to plant *tifro*on farmland and *wolele* in their homegardens (Table 2). According to the respondents, *tifro* is the dominant bamboo landrace and more important than *wolele* in the Machakel District, East Gojjam Zone. *Tifro* is morphologically characterized by its rough and large culms, which are rigid and difficult to split when producing various items of household furniture. The culms are yellow when mature, and have characteristically tough rudimentary aerial roots on each node, which give this landrace the name *tifro*. Many respondents stated that it hasa strong culm but is highly susceptible to pests and diseases (Figure 4a). In the local market, *tifro* culms are preferred to *wolele* for their strength. Nevertheless, *wolele* culms are also used, since they have a smooth surface, and are flexible and easy to split (hence they are workable and easy to weave into baskets, mats, and shelves). The culms turn yellowish at maturity; similar to *tifro*, *wolele* is highly susceptibility to pests and diseases (Figure 4b). A serious challenge farmers face in the cultivation of these landraces is a lack of market information and a shortage of land for expanding the plantations (Table 3).

Table 2. Comparison of landraces from the Machakel District

Tifro	***Wolele***
Culm has a thicker diameter than *wolele* Longer culm height than *wolele* Nails (protruding rudiments of aerial roots) present at the nodes	Thinner culm diameter Shorter culm height Nails absent at the nodes (no rudiments of aerial roots)
Strong so rigid when bending Culms are difficult to split to make into various household products and stripes are rough	Flexible culm and stripes, preferred for making various household and marketable products Easy to split, less resistant, and stripes are smooth
Turns yellow when mature Highly susceptible of insect pests	Culm color turns yellowish when mature Highly susceptible to borers and powder-post insect pests

Table 3. Bamboo landraces planted in the Machakel District, East Gojam Zone, Amhara Region, and problems experienced

Study variables	Household response	Frequency	Percent
Landraces found on farmlands	*Tifro* only	8	26.7
	Wolele only	1	3.3
	Tifro and *wolele*	21	70
Preferred landrace	*Tifro*=1st	23	76.7
	Wolele =1st	7	23.3
Current bamboo planting	Yes	7	23.3
	No	23	76.7
Major problems associated with bamboo promotion	Land shortage	16	53.3
	Lack of market information	7	23.3
	Both land shortage and lack of market information	7	23.3

Figure 4. Landraces: a) *Tifro* and b) *Wolele*, found in the Machakel District, East Gojam Zone, Amhara Region

3.1.3 Chencha Zuria District

During the field survey, it was established that there are five landraces known in the Chencha District, namely, *lodo, tsarzo, lala, solko* and*na'a* (Figure 5). All respondents mentioned that they plant one or more of the landraces on their farmland and in their homegardens.

Respondents explained that *tsarzo, lala* and *lodo* are the preferred landraces, followed by *solko* and *na'a*. In the Chencha District, farmers mentioned that a shortage of land, monkeys, damage caused by porcupines and mole rats, a shortage of labor, moisture stress, a perceived decline in soil fertility due to bamboo, and lack of market avenues and market information are the production constraints (Table 4).

Farmers' preference for *tsarzo* is related to its mechanical strength compared to the other landraces, its durability, and its resistance to borer insects. *Lala* grows faster than the other landraces and produces more culms per unit area, and can be processed into multiple types of products. Growers also fetch higher market prices from selling the culms of *tsarzo*. *Lodo* has thicker inner flesh and walls, and also yields more culms per unit area (higher productivity) than *lala*, which is processed into multiple products and has a higher market value (Table 5).

Table 4. Highland bamboo production constraints in the Chencha District

Production constraints	**Priority problem**
Shortage of land	1
Monkeys, porcupines, and mole rats	2
Shortage of labor	3
Moisture stress	4
The perception that bamboo affects soil fertility	5
Lack of market avenues and market information	6

Table 5. Summary of the highland bamboo landraces characteristics in the Chencha District, Gamo Zone, the SNNPR

Lodo	***Tsarzo***	***Lala***	***Solko***	***Na'a***
The culm is yellowish-green when mature; has a thicker inner part than other landraces; when dry the outer part is difficult to split or	The culm is yellowish-brown when mature; has long internodes; thin in diameter and stronger compared to	The culm has a variable color, notably with stripes. The culm is soft and flexible while working, easily harvestable.	The culm has a large diameter; it is strong and difficult to cutting; the outer part of the split culm is peeled from the flesh and used for	The culm is greenish in color, and the nodes have very conspicuous rudimentary aerial roots or hardened nail-like structures. There are thick and tufted dense

separate from the inner flesh. Commonly used for fencing; it is susceptible to borers and hence not preferred for house construction.	other landraces. It is themost preferred landrace for house construction, furniture, and decoration. The culm can be split with a sharp knife while working. Susceptible to termite attacks.	The culm has a high productivity per unit area and is commonly used for weaving. Produces fodder leaves for ruminant livestock. Susceptible to borers and beetles.	house construction. The large hollow culm cut nearthe basalnodeis used for fetching water from streams, and also serves as a urine collector for the elderly. The leaves and twigs are short and erect. Susceptible to powder-post beetles and termites.	branches on the nodes; they often break from the nodes while splitting. This landrace morphologically resembles the *hikonota* landrace of the Hulla District and the *thilla* landrace of the Arbegona District of the Sidama Region. It produces a dense leaf biomass for livestock fodder. It is commonly attacked by powder-post beetles and termites.

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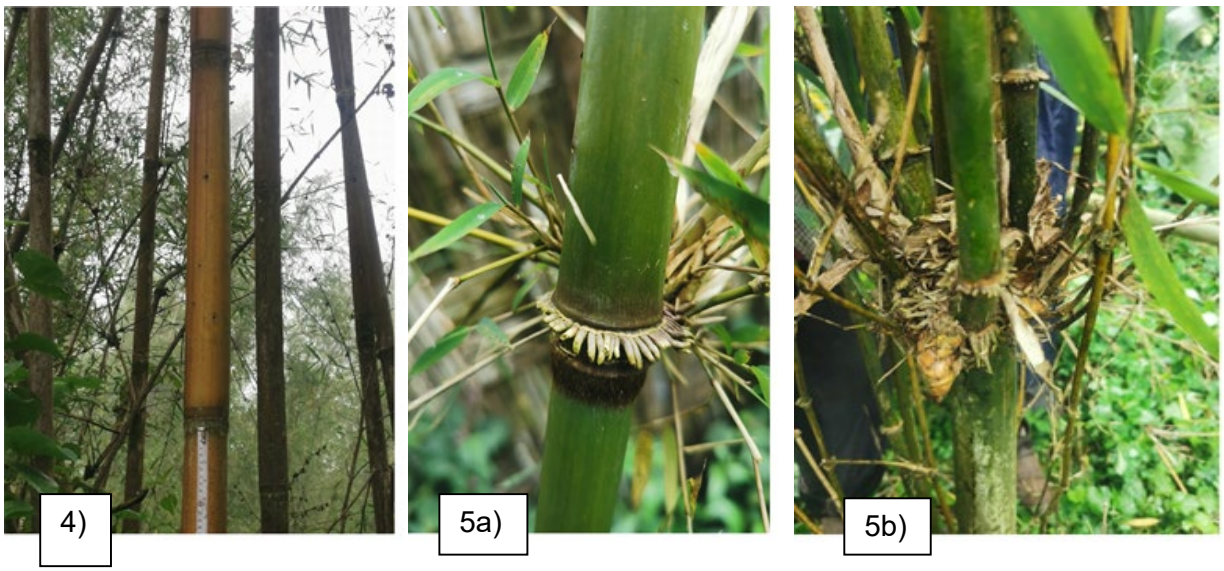

Figure 5. Distinct landraces of highland bamboo as described by knowledgeable farmers: 1) *Lodo*, 2) *Tsarzo*, 3) *Lala*, 4) *Solko*, 5a) *Na'a* with nail-like protrusions on the nodes, 5b) *Na'a* with tufted massive branches in the Chencha District, Gamo Zone.

3.1.4 Hula District

In this research study, we found two bamboo landraces in the Hula District of the Sidama Region, namely *hinkonota* and *hinkonokita*. The name *hinkonota* in Sidama means a bamboo landrace which possesses nail-like protrusions or dried-up aerial roots on the nodes of the culm (Figure 6). On the other hand, *hinkonokita* means a bamboo landrace which has no protrusions on the culm node, or culms with smooth nodes. Growers and processors in the district prefer the *hinkonota* landrace for its productivity, workability, and strength.

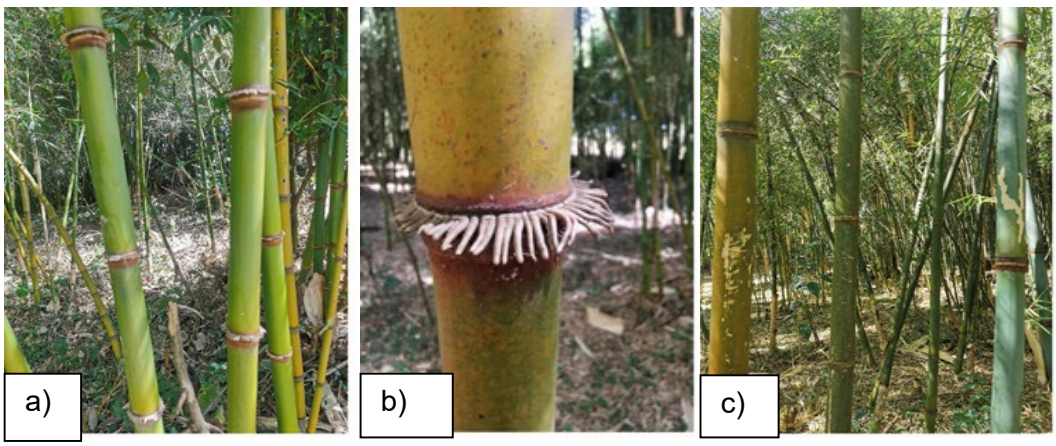

Figure 6. a) *Hinkonota* (nodes with nails) young culm, b) *Hinkonota* (mature culm node with nails), and c) *Hinkonokita* (nail-less) or culms with smooth nodes

3.1.5 Arbegona District

In the Arbegona District of the Sidama Region, we identified five different landraces of highland bamboo, as described by the farmers and processors (Table 6). The landraces observed are *ganticha, midasho, sella, shosharqa*, and *thilla*. Of the five landraces, *midasho*, *ganticha*, and *sella* are the most preferred ones, ranked from first place to third, respectively (Table 7). Their greater preference is based on their higher biomass production, preference in the market, and better income generation. Similar is the trend of ranking for the landraces on the farmers' land. *Midasho* is widely grown in the Arbegona District for its culm productivity per unit area, preferred use for house construction, fencing, household furniture, and workability to process into different products.

Thilla resembles *hinkonota* (*tirsyalew*) of the Hula District and *Na'a* of the Chencha District, whereas *midasho* resembles *hinkonokita* (*tirsyelelew*) of the Hulla District. On the other hand, *sella*, with its long and strong internodes, resembles *tsarzo* of the Chencha District.

Table 6. Summary of the highland bamboo landraces' characteristics in the Arbegona District

Ganticha	***Midasho***	***Sella***	***Shosharqa***	***Thilla***
Relatively big in size (culm thickness). Hook-shaped nails drop after some time.	Thin flesh with wider hole in the internode. Hookless/smooth nodes without nail-like structures. Culm diameter and height relatively large in size. Most preferred by farmers.	Long internodes. The culm is claimed to have similar strength to *tsarzo* in the Chencha District.	The internodes are long. Fleshy internodes have narrow interior holes. Hook-shaped nails drop after some time.	Hook-shaped nails like protrusions on the nodes.

Figure 7. Highland bamboo landraces found in the Arbegona District of the Sidama Region: 1a) *Ganticha* productive stand, 1b) *Ganticha* with detaching nails, 2a) *Midasho* young culm with shedding nodal nails, 2b) *Midasho* mature culm with smooth nodes, 3) *Sella* with long culm4a) *Thilla* culm, 4b) *Thilla* with dense branching, 5a) *Shosharqa* with rudimentary nails 5b) *Shosharqa* with long internode.

Table 7. Farmers' preferences for landraces and availability on farmers' land in the Arbegona District, Sidama Region

Ranking of farmers' preferences for landraces		**Availability of landraces on farmers' land**	
Landraces	Rank	Number of farmers	Rank
Midasho	1	28	2
Ganticha	2	30	1
Sella	3	25	3
Thila	4	22	4
Shoshorqa	5	21	5

3.1.6 Gumer District

In the Gumer District of the Guraghe Zone, growers identified three types of highland bamboo landraces, namely, *Agadie*, *Benejie* and *Ankefuye*. Of the three landraces, *Agadie* is preferred because of its wide use in local house construction (Table 8). It is more preferred in the market for its high commercial value, fast growth, thicker culm diameter, greater yield per unit area, and greater split culm volume because of the larger culm diameter (Figure 8).

Table 8. Description of highland bamboo landraces' characteristics in *Agadie*, *Benejie* and *Ankafuye* in the Gumer District of the Gurage Zone, the SNNPR

Agadie	***Benejie***	***Ankafuye***
Landrace with large-diameter culm and large height. Green when young, gray or reddish when mature. High-yielding landrace (double yield) compared to others. Produces more shoots annually. Erect culm; used for furniture, fodder, and income generation.	Landrace with medium-diameter culm and medium height. Green when young, gray or reddish when mature. Medium-yielding landrace compared to *agadie*. Preferred for local broom production.	Landrace with small-diameter culm and short height. Culm growth habit is of the spreading type. Low-yielding landrace compared to *benejie*. Preferred use is for fencing.

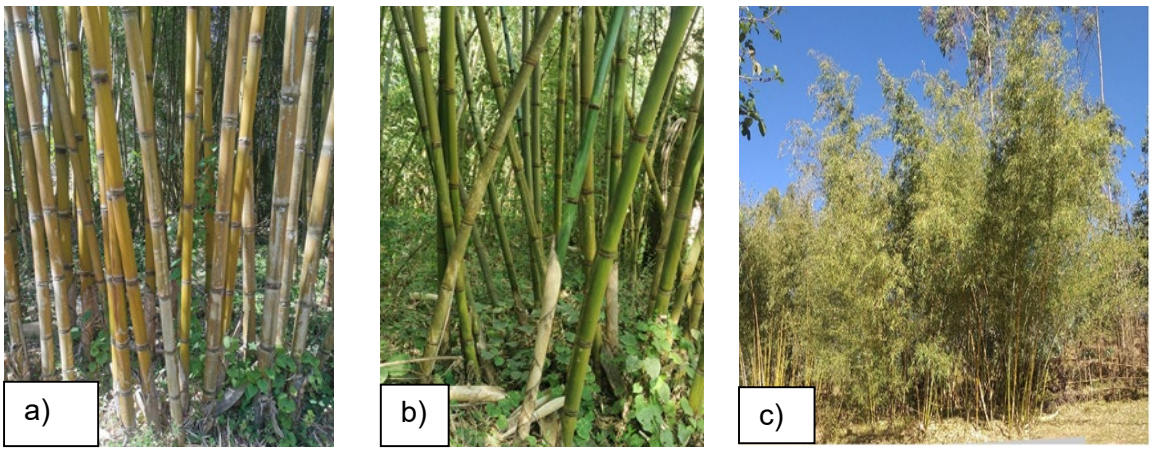

Figure 8. Highland bamboo landraces as described by knowledgeable farmers in the Gumer District, the Gurage Zone, the SNNPR: a) *Agadie*, b) *Benejie*, c) *Ankafuye*

3.1.7 Masha District

In the southwestern regional state of Ethiopia, Sheko Zone, the Masha District is known for its dense highland bamboo planted forest. Farmers in the district are acquainted with three highland bamboo landraces widely grown for different purposes. The three landraces known in the area are *shimiti, michi* and *demamu* (Table 9; Figure 9).

Table 9. Summary of the highland bamboo landraces' characteristics in the Masha District

Shimiti	***Michi***	***Demamo***
Deep green in color; large-diameter culm and large height. The culm is smooth with no nodal nail-like protrusions. Preferred for making beehives.	Greenish pale culm with relatively longer internodes; culm nodes with nail-like protrusions. Dense culm production per unit area. Used for making beehives and fencing compounds.	The culm has a dark-brown color; culm is medium in size with detaching nodal nail-like protrusions. The split culm is used for making enset and decorating tools.

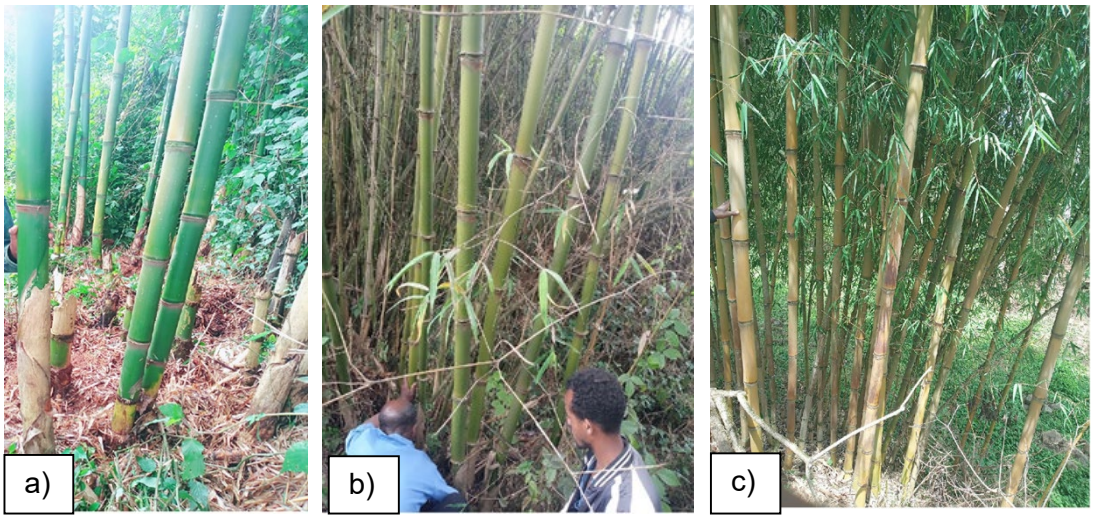

Figure 9. Bamboo landraces from the Masha District, Sheko Zone, South-West Ethiopia Regional State: a) *Shimiti*, b) *Michi*, c) *Demamo*

3.2 Growth characteristics of highland bamboo landraces in Ethiopia

In the survey of seven administrative zones of Ethiopia, 24 landraces were identified. Most of the landraces were found in the Gamo and Sidama Zones, and the fewest were found in the Jimma Zone (Table 10). Samples taken from landraces were used to describe their above-ground and below-ground growth characteristics. The description of the above-ground characteristics included the DBH, height, and internodal length. The below-ground characteristics included the length and width of the rhizome neck and the rhizome proper.

Table 10. Number of described landraces in eight zones and eight respective districts

S.No.	Zone	District	Relative location	Number of described landraces
1	Gurage	Gumer	Southern Ethiopia	3
2	Gamo	Chencha	Southern Ethiopia	5
3	Sheka	Masha	Southern Ethiopia	3
4	Sidama	Hula	Southern Ethiopia	2
5	Sidama	Arbegona	Southern Ethiopia	5
6	Awi	Banaja	Northwest Ethiopia	3
7	West Gojjam	Machakel	Northwest Ethiopia	2
8	Jimma	Seka-Chekorsa	Southwest Ethiopia	1

		Total		24

Above-ground growth characteristics: Nine of the 24 landraces described have average values for all the above-ground characteristics, namely, DBH (5.4 cm), height (11.5 m), and internode length (41.4 cm). The maximum values for the landraces which had above-average values were as follows: DBH from 7.2 cm (*benejie*) to 9.6 cm (*danticha*), height from 8.6 cm (*lala* and *lodo*) to 13.12 cm (*shosharqa*), and internode length from 42 cm (*lala* and *lodo*) to 58 cm (*ganticha*). The landraces which had above-average values in all three growth parameters were *ganticha*-Arbegona*, shosharqa*-Arbegona*, agadie*-Gummer*, midasho*-Arbegona*, na'a*-Chencha*, tifro*-Machakel*, benejie*-Gummer*, lala*-Chencha *and lodo*-Chencha (Table 11; Figures 10–12).

Two landraces, namely *zingurgur*-Banja and *tarzo*-Chencha, have the longest average internode lengths (52 cm, with a maximum value of 63 cm, and 50.25 cm, with a maximum value of 58 cm, respectively). The landraces of *na'a*-Chencha, *tifro*-Machakel, *agadie*-Gummer, *wolele*-Machakel, *midasho*-Arbegona, *tikuro*-Banja, *ganticha*-Arbegona, *shosharqa*-Arbegona, and *michi*-Masha have average internode lengths which are above the overall average length of all the studied landraces (Table 11).

In the Seka Chekorsa District of the Jimma Zone, farmers manage a type of highland bamboo, locally called *lemman,* on their private lands; many of the farmers' bamboo sites are inherited from their forefathers. From the discussions and field visits we had in three localities, we deduced that there are no well-defined landraces in the area. The highest DBH (average 10.5 cm; max 12.4 cm) and height (average 17.5 m, maximum 18 m) of all the landraces were recorded in the Seka Chekorsa District. However, the values of the measured internode lengths (average 38.40 cm and maximum 50 cm) were found to be lower than the average values of the nine landraces identified as having above-average values for all the above-ground parameters.

The measured values, both for DBH (average 2.13–2.82 m) and height (average 8.5–11 m), of the three landraces of *shimit*, *demamo* and *michi* found on farmers' fields in the Masha District were unacceptably low, which could be ascribed to poor management of the selected bamboo site conditions. However, at nearby study sites, Kassahun et al. (2005) reported an average DBH value of 7.6 cm and an average height of 16.8 m, which is comparably very high. This might be associated with relatively poor bamboo management and protection from

livestock encroachment on the current site. On the other hand, in contrast to the low DBH and height values at the Masha site, relatively higher values were recorded for internodal length.

Standard deviation values, which is the square root of variance, gives a very good insight into the traits of the landraces studied. Landrace *thilla* of the Abergona District shows a very good genetic variation (within landrace) with 5.7±1.2 cm for DBH and 11.5±21 m for height. For internodal length, the variation for the landrace *ganticha* of the Abergona District was the most, at 43.2±8.1 cm. The mean, range, and standard deviations of the traits are measurable descriptors used to estimate the phenotypical and genetic variations of the species (Thakur et al., 2015).

Table 11. Above-ground growth characteristics of highland bamboo landraces in different zones of Ethiopia

	Culm DBH (cm)	**Culm height (m)**	**Internode length (cm)**
Name of landrace	Mean+SD	Mean+SD	Mean+SD
Seka Chekorsa District, Jimma Zone, Oromia Region			
Lemman	10.5+0.72	17.5+1.2	38.37+6.4
Arbegona District, Sidama Region			
Ganticha	8.2+0.8	13+1.11	43.2+8.1
Shosharqa	7.2+1	13.6+0.85	41.6+6.9
Midasho	6.9+0.9	12.6+1.84	44.3+6.7
Thilla	5.7+1.2	11.5+2.1	36.6+5.6
Sella	4.5+0.6	10.6+1.22	39.4+5.3
Gummer District/ Gurage Zone, SNNPR			
Agadie	7±1	14±2	46±4
Benejie	6±1	12±1	41±5
Ankefuye	3+0	7+1	24+2
Chencha District, GamoZone, SNNPR			
Na'a	6.9+0.7	10+0.9	49+4.5
Lala	5.6+0.6	8.6+0.7	41+3.2
Tsarzo	4.98+0.45	10.86+1.2	50.25+4.4
Lodo	5.5+0.7	9.3+1.2	43.8+3.6
Solko	8.56+.49	14.92+0.31	62.18+5.13

Machakel District, West Gojjam Zone, Amhara Region			
Wolele	5.05±0.24	11.52±0.31	44.77±1.15
Tifro	6.16+0.18	13.12+0.51	46.27+0.93
Hula District/Sidama Region			
Hikonokita	5.4±0.6	12.2±2.4	37.6±7.2
Hikonota	5±0.8	11.9±2.6	36.8±6
Banja District, Awi Zone, Amhara Region			
Tikuro	4.6±0,6	12.5±1.3	43.6±4.7
Zingurgur	5.2±9.7	11.2±0	52±6.1
Qeyo	3.7±0.8	10.4±2.6	39±6.7
Masha District, Sheka Zone, South-Western Ethiopia Region			
Shimiti	2.82±11	11±1	40.5±3.9
Demamo	2.17±8.5	8.5±0.5	35.43±4.85
Michi	2.13±10.5	10.5±2.5	41.33 ±3.7
Average of all landraces	**5.39**	**10.64**	**42.42**

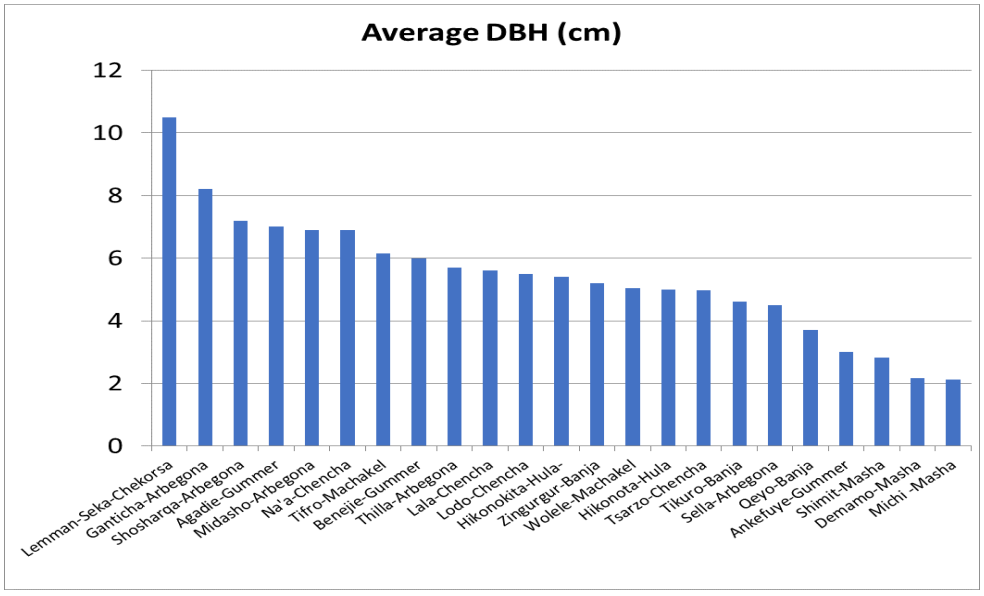

Figure 10. DBH (cm) of highland bamboo landraces in different zones of Ethiopia

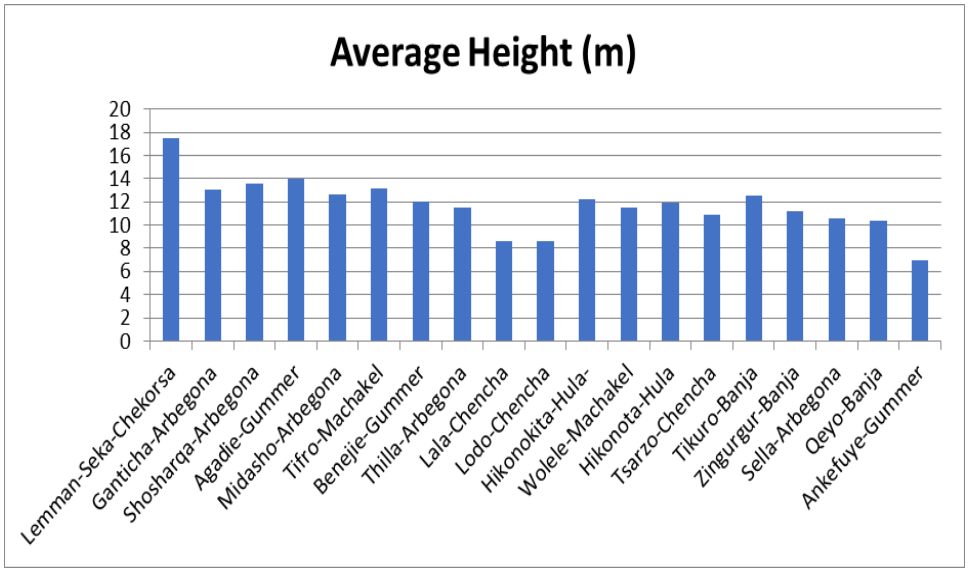

Figure 11. Height of highland bamboo landraces recorded in different zones of Ethiopia

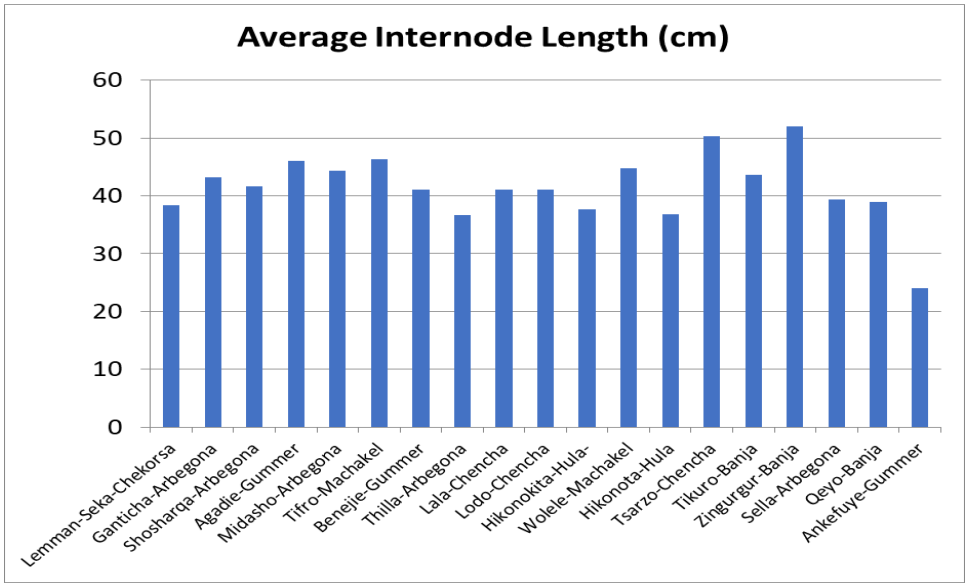

Figure 12. Internode (bottom) growth values of highland bamboo landraces in eight districts of Ethiopia

3.3 Rhizome morphology of highland bamboo landraces

The rhizome, the underground part of a bamboo plant, is the foundation and source of emerging shoots, which finally grow into culms. The larger the size of the rhizome of a bamboo plant, the larger the produced shoots and recruited culms will be. The two main parts of the rhizome, that is, the rhizome neck and the rhizome proper (Figure 13), are important indicators of the above-ground performance of the bamboo plant.

In this study, we observed the practical and technical aspects of the rhizome. The rhizome neck of the highland bamboo is solid and tough to cut, and it is difficult to extract from the grove. It requires digging deep into the surrounding soil, until the rhizome is exposed, so that cutting becomes easier. Cutting the rhizome neck requires sharp tools.

On a sloping terrain, if there are also other woody plants, the rhizome penetrates through tree roots or becomes interlocked on its way upwards and/or downwards. Depending on the position of the rhizome on the ground, all the rhizome necks of a plant may move upwards together (Figure 14A), or half of the rhizome necks lead upwards and the remaining rhizome necks go downwards (Figure 14B). Thus, the non-uniformity of the rhizome growth belowground, and the variation in soil and plant management, such as the compaction of the soil and the presence of stumps near certain rhizomes, make it difficult to characterize the growth. Moreover, as the sampling method we followed was a destructive method, some farmers were not willing to provide access to excavate rhizomes from their bamboo forests.

The rhizome types of 23 highland bamboo landraces are described in this study (Figures 13 and14): They are sympodial, with the length of the neck varying from one landrace to the other, like the size variations observed in the above-ground growth characteristics. Our findings are in line with those of Yigardu and Masresha (2011), who described four highland bamboo landraces by studying 72 plants in one specific uniform church bamboo forest at Choke Mountain, North Western Ethiopia. The rhizome proper of all the landraces in the present study, like that described Yigardu and Masresha (2011), clearly indicate that it was nearly vertically positioned and exhibits a sympodial branching pattern.

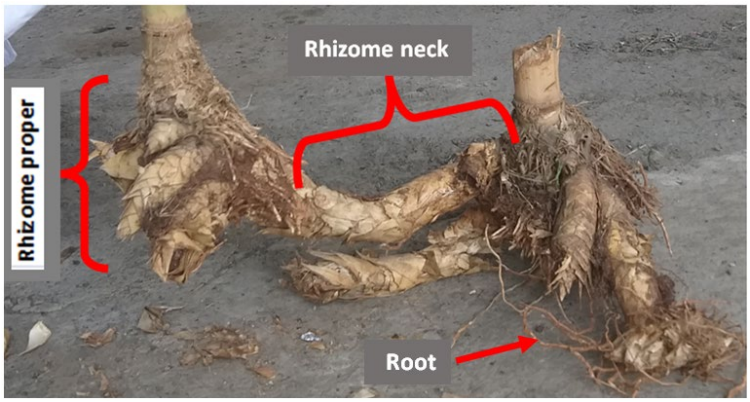

Figure 13. Typical rhizome morphology of highland bamboo landraces in Ethiopia showing the rhizome neck, the rhizome proper and the roots

Figure 14. Rhizome morphology of highland bamboo landraces as affected by topography: (A) two visible succeeded mother rhizomes grown upwards along the slope, the third developed but was aborted; (B) a succeeded mother rhizome grown creeping along the slope, the only one suceeding mothe rhizome is viible, the second being aborted similrly; and (C) rhizome neck growth in a flat terrain, finally the rhizome proper being nearly vertically oriented.

Rhizome characteristics of highland bamboo landraces: Three sample plants (of a relatively small sample size) were used from each available landrace at each study site. The length and thickness of the sample rhizome neck and of the rhizome proper were measured (Table 12) for 14 landraces. *Agadie* (19 cm), *benejie* (19 cm), *hikonota* (18.7 cm), *hikonokita* (25 cm), *tifro* (18.44 cm) and *lemman* (25 cm) had above-average (16.54 cm) rhizome neck lengths, which indicates that the above-ground culm spacing of the landraces is highly diffused as compared to other described landraces. A study in northwest Ethiopia (Yigardu and Masresha, 2011) indicated that *tifro*-Sinan landrace, which is similar to *tifro*-Machakel (Amsalu et al., 2021), has diffused culm spacing as compared to the short, naked landrace *welele*-Sinan, which is similar to *welele*-Machakel described in this study.

The rhizome neck lengths (Figure 15) of *tifro*-Sinan (average 17 cm, max. 30 cm), compared to *welele*-Sinan (average 11 cm), indicate a significant difference in rhizome neck length; therefore, while the number of culms per ha is low, the plant size is larger for tifro-Sinan (culm density 14,200, average DBH 5.3 cm, average height 13.9 m) compared to welele-Sinan (culm density 14,767, average DBH 4.9 cm, average height 12.7 m) (Yigardu and Masresha, 2011).

The bamboo in the Jimma Zone has the highest values in terms of rhizome neck length (25 cm) and rhizome neck thickness (7cm). The landraces which the community calls *hikonokita, shimit, agadie* and *benejie* have higher values in terms of the length of their rhizome necks. The rhizome neck length of *agadie, kerkeha*-Jima zone*, tifro* and *wolele* have the top values in terms of rhizome neck thickness (Figure 16).

Table 12. Rhizome characteristics of highland bamboo landraces in Ethiopia

S.No.	Name of landrace-growing district	Average length of the rhizome neck (cm)	Average thickness of the rhizome neck (cm)	Average length of the rhizome proper (cm)	Average thickness of the rhizome proper (cm)
1	Agadie-Gummer	19.00	7.00	11.00	-
2	Benejie-Gummer	19.00	4.00	17.00	51.00
3	Ankefuye-Gummer	14.00	4.00	15.00	41.00
4	Lodo-Chencha	12.70	3.40	7.20	5.80
5	Lala-Chencha	11.60	4.20	10.40	7.30
6	Tsarzo-Chencha	13.80	3.60	11.90	6.70
7	Hikonota-Hula	18.70	-	10.70	-
8	Hikonokita-Hula	25.00	-	4.50	-
9	Tikuro-Banja	11.40	1.90	12.20	5.60
10	Qeyo-Banja	14.30	4.00	14.80	6.50
11	Tifro-Machakel	18.44	5.82	19.00	9.20
12	Wolele-Machakel	14.78	4.73	18.00	7.55
13	Lemman-Seka-Chekorsa	25.00	7	20.00	53.00
14	Wonde-Sinan	17	3.8	19.6	14.7
15	Welele-Sinan	11	3.7	23.1	14.7
16	Tifro-Sinan	12	4.1	20.5	15.1
	Average (for landraces 1–13)	**16.54**	**10.55**	**14.29**	**23.78**
	Min	**9.00**	**1.90**	**4.50**	**5.60**
	Max	**29.00**	**60.70**	**31.00**	**73.00**

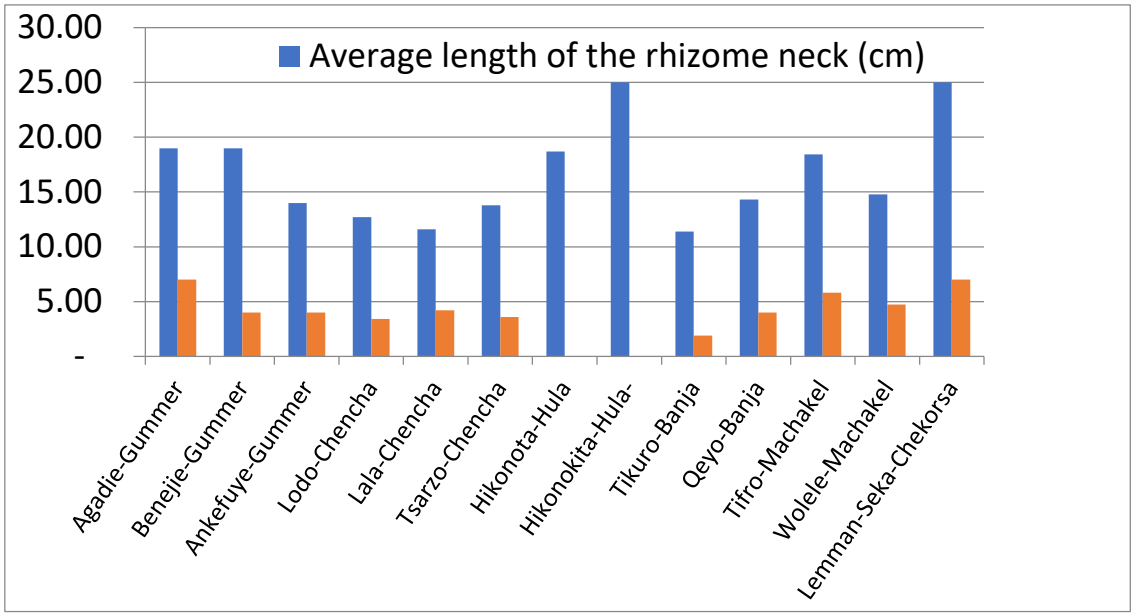

Figure 15. Growth characteristics of the rhizome neck of highland bamboo landraces

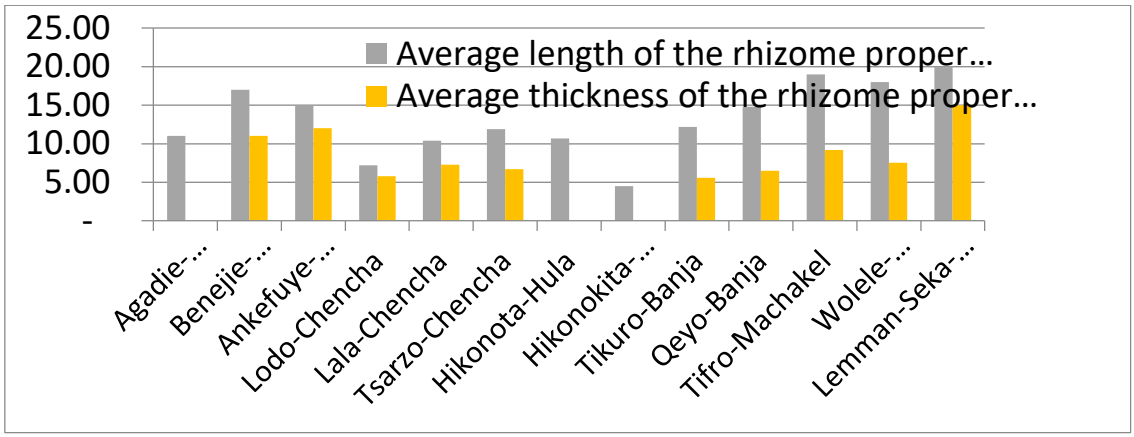

Figure 16. Growth characteristics of the rhizome proper of highland bamboo landraces

3.4 Suitability of highland bamboo landraces for different applications

Bamboo has many uses for local communities in different parts of Ethiopia, mainly in construction (flooring, roofing), indoor utensils, food, leaves for mud fixer, animal feed, fuel, fabrics, charcoal, etc. (Yohannes et al., 2019; Melaku, 2017). Because of its properties such as elasticity, wooden-like strength, elegance, and lightweight, bamboo has emerged also as the most versatile material for construction in different parts of the world, for example in India, South America, Africa, and some parts of Asia (Rashmi et al., 2022). The bamboo plant has many important benefits and uses, both as a growing plant and for its harvested resources.

In all the districts of Ethiopia included in this study, highland bamboo growers have a culture of harvesting and utilizing bamboo culms for different purposes. The number of culms harvested and used per household per year varies from household to household, and also from district to district. This could be attributed to the size of the landholding occupied by households, as well as productivity, which is usually based on the climatic condition of an area and the growing site conditions of the district. Research in the Banja District revealed that bamboo growers harvested, on average, 511 culms per year, while the minimum and maximum varied between 40 and 5,000 culms. In the Arbegona District, the average number of culms harvested per household per year was 711, and the minimum and maximum varied between 200 and 3,000. These figures vary from district to district, depending on the size of landholdings, the productivity of the landraces, and the management applications by the owners on the growing sites.

In the Banja District, most of the respondents (63.3%, n=30) sell mature culms to local bamboo processors, with the processors either coming to the village of the bamboo growers or the growers taking the bamboo culms to the nearby village markets. This means that the larger proportion of growers do not produce bamboo products themselves. The rest, 37.7% of bamboo growers, produce local products, such as woven bamboo sheets, tables, chairs, shelves, and baskets, from harvested culms. By comparison, in Machakel District, most of the respondents (60%) utilize bamboo culms in raw (round) form, rather than process them into other local products. However, 40% of the respondents utilize bamboo culms, after processing it into local products.

This study revealed the existence and use of different bamboo landraces for several purposes by the communities in the study areas. For example, in the Banja District the top five reported purposes of planting bamboo landraces were for house construction, fencing, woven bamboo products, small-scale bamboo products, and household utensils (Figure 17).

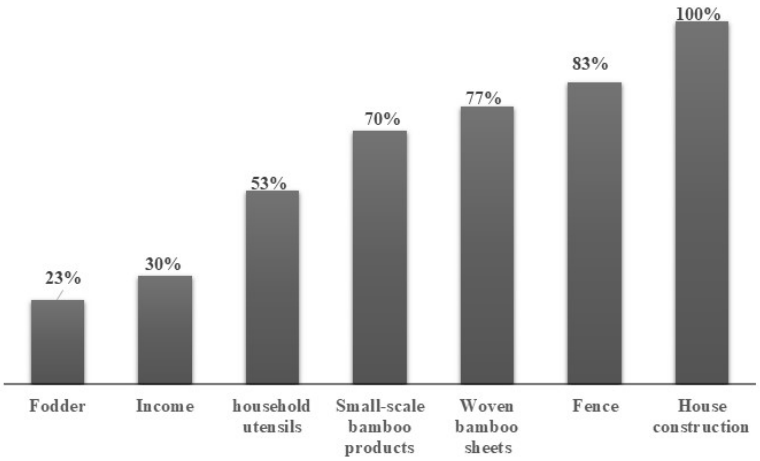

Figure 17. The purposes for which local communities plant bamboo in the Banja District

According to the respondents, there are differences in the preferences and uses of different highland bamboo landraces for different products and purposes, although there are some similarities. The household interviewees and group discussion respondents in Machakel District mentioned that the landrace *tifro* is more important, or preferred, for house construction, fencing, chicken coops, and woven bamboo products, while *wolele* is more important for the production of woven local products such as *akenbalo, tirar, qimba* and *mesob* (all are local household items). In the Gumer District of the Gurage Zone, the *ankefuiye* landrace is preferred for fencing, whereas *agade* is preferred for house construction, fencing, enset processing, decorating tools, woven local house doors, and inner compartmentalization or separation walls for local houses.

In the Chencha Zuria District, *tsarzo* landrace, for example, is preferred for house construction and local bed manufacturing, as it is stronger and more durable compared to the other landraces. In the Arbegona District, farmers use five landraces, namely, *ganticha, midasho, thilla, sella*, and *shosharka* for different purposes. For example, *ganticha* is preferred for fencing and house construction. *Sella* is also used for house construction, particularly for roofing, as it is resistant to powder-post damage by beetle insects. Nevertheless, *midasho* is preferred by the market for income generation, as it has a large culm size.

Generally, farmers traditionally use the landraces for various applications based on their properties and evidence of their suitability for different uses. However, bamboo industries utilize the resources without recognizing the differences between the landraces. Therefore,

there is a need to conduct research focusing on the characteristics and suitability for application of the different landraces, as there may be anatomical and mechanical differences. Moreover, the research should focus on recommendations of preferred uses of various landraces for specific products or purposes, in order of priority.

4. Conclusion

This ethno-taxonomic study revealed the number of available highland bamboo landraces in Ethiopia based on their dendrometric and morphological traits. From the Amhara, Oromia, Southern Nations Nationalities and Peoples' Region, South-Western Ethiopia and Sidama regions, eight districts were selected for the investigation of the presence and characteristics of highland bamboo landraces. The districts were selected based on the long tradition of growing highland bamboo in the respective regions. The study identified and described 23 landraces and their distinct morphological differences and traditional uses. Morphological similarities among landraces were also observed, as well as overlapping use categories. For instance, the *na'a* landrace from the Chencha District was found to have similar morphological traits to that of *hinkonota* from Hula, *tifro* from Machakel, *michi* from Masha, and *thilla* from Arbegona. These highland bamboo landraces were observed to have conspicuous nodal nail-like protrusions or hardened aerial roots, and dense branching habits with massive leaf biomass production, often breaking at the nodes while splitting for processing into different products. By comparison, the *tsarzo* landrace from Chencha, with its long internode length and strength, is similar to *sella* from Arbegona, which is widely preferred for erecting the skeletal foundation when building traditional houses in the districts. Landraces that are widely grown and produced for market include *lala* and *lodo* from Chencha, *hikonokita* from Hula, *midasho* and *ganticha* from Arbegona, *shimiti* and *demamu* from Masha, and *agade* from Gumer, in the Gurage Zone.

Based on the preference of knowledgeable local bamboo processors and the quality features observed in the landraces from each of the specific sites, we recommend that landraces such as *lala*, *lodo*, *tsarzo*, *hikonokita*, *sella*, *midasho*, *ganticha*, *shimiti*, *demamu*, *tikuro* and *agade*be widely promoted to new areas in the highlands for use in wood-based industries for the production of quality end products. We also suggest that genetic variability be checked through standard procedures to complement our findings and verify the existence or absence of differences among the landraces identified in the different geographic locations.

The agro-ecology and the range of altitudes where highland bamboo grows across the country notably exhibits the following common parameters: altitude between 2,300 and 3,500 m, receiving a higher amount of rainfall, a cool climate as low as 6°C to as high as 30°C, and a slightly acidic soil (pH 5–6). Therefore, we recommend that landraces from different growing regions be collected and planted in at least three regions to monitor their growth performance

and the same be used for genetic conservation. A further genetic variability study can also be conducted with these collections.

Characteristics such as hard aerial roots on nodes or protruding knots on the nodes, if consistent within a population, might become a varietal difference on the taxonomic scale. If more than one qualitative morphological feature such as the colors of the culm, or the presence/absence of nail-like aerial roots, are persistent in the population, then the bamboo population may be examined for interspecific variations using molecular tools. It is also suggested that the ploidy levels of landraces be studied.

References

Amsalu, N., Menale, W., Asmamaw, A., Wubalem, T.andC. Yazie. 2021. Indigenous management practices of highland bamboo (*Yushania alpina*) in West Amhara, Ethiopia. *Cogent Food & Agriculture,* 7:1, 1926683, DOI: 10.1080/23311932.2021.1926683.

Brias, V., Tesfaye, H., and J. Hierold. 2009. 'Bamboo Cultivation Manual Guidelines for Cultivating Ethiopian Highland Bamboo'. *Eastern Africa Bamboo Project*, 58.

Bystriakov, N., Valerie, K., Chris, S., and L. Igor. 2003. 'Bamboo Biodiversity Information for Planning Conservation and Management in the Asia-Pacific Region'.

Calvet-Mir, L., Maria, C. M., Laura, V.N., and R. G. Victoria. 2011. 'Landraces in Situ Conservation: A Case Study in High-Mountain Home Gardens in Vall Fosca, Catalan Pyrenees, Iberian Peninsula1'. *Economic Botany65* (2):146–57. https://doi.org/10.1007/s12231-011-9156-1.

Casañas, F., Joan, S., Joan, C., and P. Jaime. 2017. 'Toward an Evolved Concept of Landrace'. *Frontiers in Plant Science8* (FEBRUARY):1–9. https://doi.org/10.3389/fpls.2017.00145.

Chen, T.H., Dar, H.W., and W. Shitephen. 2016. 'The Trend of Growth Characteristics of Moso Bamboo (*Phyllostachys Pubescens*) Forests under an Unmanaged Condition in Central Taiwan'. *Taiwan Journal of Forest Science31* (2):75–88.

Ensermu, K., Tamrat, B., Alemayehu, G., and H. Gebremedhin. 2000. 'A Socio-Economic Case Study of the Bamboo Sector in Ethiopia: An Analysis of the Production-to-Consumption System'. http://www.inbar.int/sites/default/files/resources /inbar_working_paper_no25.pdf.

Getachew,D. and T. Wubalem. 2014. 'Resource Communication. Resource Potential of Bamboo, Challenges and Future Directions towards Sustainable Management and Utilization in Ethiopia'. *Forest Systems23* (2):294–99. https://doi.org/10.5424/fs/2014232-03012.

Hedberg, I. & Edwards, S. (eds.). 1995. *Flora of Ethiopia and Eritrea 7*: 1-430. The National Herbarium, Addis Ababa University, Ethiopia & The Department of Systematic Botany, Upps.

Irawan, B., Partasasmita, R., Rahayu, N., Setiawati, T., &J. Iskandar. 2019. Indigenous knowledge of bamboos by Naga community, Tasikmalaya District, West Java, Indonesia. *Biodiversitas, 20*(5), 1423–1434. https://doi.org/10.13057/biodiv/d200535

Lobovikov, M., Paudel,S., Piazza,M., Ren,H., and J. Wu. 2007. 'World Bamboo Resources: A Thematic Study Prepared in the Framework of the Global Forest Resources, Assessment 2005'. *FAO Technical Papers*.

https://doi.org/http://library.duke.edu/catalog/search/recordid/DUKE004081693.

Melaku, M.2017. Multiple Uses of Bamboo Species and Its Contribution to Forest Resource Management in Ethiopia. *Journal of Resources Development and Management 32*: www.iiste.org ISSN 2422-8397.

Mera, F. A. T., and C. Xu. 2014. 'Plantation Management and Bamboo Resource Ecconomics in China'. *Ciencia Y Technologia* 7 (1):1–12.

Mishra, V. 2015. 'Bamboo and Its Connectivity to the Different Fields of Economics: A Potential Resource of Modern India'. *International Journal of Innovative Research & Development 4* (2):140–45.

Mulatu, Y. and F. Masresha. 2011. 'Morphology and Biomass Variations of Arundinaria Alpina Landraces in the Choke Mountain, Northwestern Ethiopia'. *Journal of Bamboo and Rattan10* (3–4):77–93.

Mulatu, Y. and F. Masresha. 2011. Morphology and biomass variations of *Arundinaria alpina* landraces in the Choke Mountain, Northwestern Ethiopia, *Bamboo and Rattan 10* (3&4): 77-93 (2011).

Rashmi, R., Hemant, K., Komal, P., Prathmesh, A., Manish, K., Atya, K., Ashok, P., Mukesh, K., Awasthi andS. Lal. 2022. Multifunctional applications of bamboo crop beyond environmental management: an Indian prospective: an Indian prospective, *Bioengineered, 13*:4, 8893-8914, DOI: 10.1080/21655979.2022.205668.

Seyoum, G., Lemma, T. and Y. Mulatu. 2018. 'Indigenous Knowledge on Highland Bamboo (*Yushania alpina*) Management and Utilization Practices in Kokosa' 13 (11):111–22. https://doi.org/10.5897/SRE2017.6552.

Thakur, A., Barthwal, S., Ginwal, H.S. 2015. Genetic Diversityin Bamboos: Conservation and Improvement for Productivity. In Bamboos in India. ENVIS Forestry Bulletin, 131-146.

Troya, M., Fidel, A., and X. Chenyang. 2014. 'Plantation Management and Bamboo Resource Economics in China'. *Ciencia Y Tecnología* 7 (1):1. https://doi.org/10.18779/cyt.v7i1.181.

UNIDO. 2009. Bamboo cultivation manual guidelines for cultivating Ethiopian highland bamboo.

Veteläinen, M., Valeria, N., and M. Nigel. 2008. European Landraces: On-Farm Conservation, Management and Use*. Bioversity Technical Bulletin No. 15.* Bioversity International, Rome, Italy.

Yared, K., Zebene, T., Abera, G. and Y. Mulatu. 2017. 'Vegetative Propagation Techniques of Highland Bamboo (*Yushania Alpina*) in Amhara Region', 61 (2):122–36.

Yohannes, W.G., Debela, H.F. and B.J. Dereje. 2019. Socio-economic importance of highland bamboo (*Yushania alpina* K. Schum) and challenges for its expansion in Bibugn District,

East Gojjam, Ethiopia. *Journal of Horticulture and Forestry 11*(2), pp. 32−41. DOI: 10.5897/JHF2018.0564. ISSN 2006-9782.

Zeven, A. 1998. 'Landraces: A Review of Definitions and Classifications'. *Euphytica104*: 127−139. https://doi.org/10.1023/A:1018683119237.

Zhou, B-Z., Fu, M-Y., Jin-Zhong, X., Yang, X-S., and Z-C. Li. 2005. 'Ecological Functions of Bamboo Forest: Research and Application'. *Journal of Forestry Research16* (2):143–47. https://doi.org/10.1007/BF02857909.

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