

# The Concept of Hierarchy in Ethnobiological Classification: On Kafficho Folk Botany of Enset (*Ensete ventricosum*) in Southwest Ethiopia

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## Abstract

Enset (*Ensete ventricosum* [Welw] Cheesman) is one of the known Ethiopian domesticates and is among the most important food security crops cultivated in the country. In Southwest Ethiopia, more notably, in Kaffa area the domestic enset coexists with its wild relatives. This study was thus conducted in Kaffa to assess the commonly applied folk wisdom of naming, identifying, and classifying ensets. The result showed that Kaffa botany of enset follows a pattern of hierarchy, beginning at the folk generic level and descending to the level of sub-variety. On the level of folk genus, farmers recognize two well-defined taxa of ensets: Uuxo (cultivated) and eppo (wild) ensets. The Eppo does not have a folk specific taxon, but Uuxo has this taxon, which is labeled as Epecho. Below the level of folk species, the Uuxo and Epecho groups divide into locally named varieties. The former has up to 92 varieties while the latter has only 3. Farmers identified 31 sub-varieties within the folk variety. Kaffa's botany of enset recognizes about 126 named, perhaps distinct units of ensets. Identification of taxa assigned to different groups is based on a wide range of folk descriptors. Among others, the Kaffa custom of naming and grouping ensets based on morphology, physiology, and utilization has definite biological and functional implications. This study has the potential to broaden our understanding of how native societies perceive, value, and maintain diversity and can also aid in the genetic and botanical study of crop plants elsewhere.

## Keywords

enset, ethnobotany, folk taxonomy, folk nomenclature, intraspecific diversity

## Introduction

The evolution of crops is affected by the management of folk cultivars in traditional agricultural systems, especially in the way in which humans act as agents of selection and dispersal (Emshwiller 2006). Conservation of crop genetic diversity often is said to be linked to indigenous knowledge and use. Thus, if we are to cognize crop evolution in customary farming systems, it is vital to study ethnobotany of folk cultivars. Understanding how crop diversity is named and classified by farmers is key to how this diversity is perceived and valued by farmers (Elias et al. 2001) and thus to understanding behavioral patterns that affect crop evolution (Quiros et al. 1990).

The invention of agriculture created great diversity among the plant species selected for domestication. This great diversity is still evident in cradle areas of domestication, maintained as ancestral varieties or landraces by traditional farmers (Brush, Carney and Huamán 1981; Harlan 1975). This is one of the hallmarks of agricultural evolution, but also presents numerous scientific issues. The dominant queries include how and why farmers in centers of crop origin maintain great diversity and what factors govern this maintenance (Quiros et al. 1990). The possible answers to these inquiries are to understand the genetic base of the crop and to describe the ways in which

farmers perceive and select crops so as to affect diversity. For whatever reason this diversity is maintained, farmers must have a specific means to do this, and a folk taxonomy and nomenclature can be helpful toward this end (Brush 1986; Quiros et al. 1990). It has been shown in Andean classification of potatoes that the folk taxonomy of great intraspecific variability can be understood as a means to maintain diversity (Brush 1992; Brush, Carney and Huamán 1981; Quiros et al. 1990; Zimmerer 1991). This article is concerned with ethnobotany of enset (*Ensete ventricosum* [Welw] Cheesman) in its center of origin and diversity, Ethiopia.

Ethiopia represents one of the main centers in the world, where crop diversity is noticeably high and some of them became domesticated (Meyer, Duval and Jensen 2012; Vavilov 1951). Of these, enset is one of the known Ethiopian domesticates and is among those crops with wild relatives in the country. It is a monocarpic perennial herbaceous plant in the

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family Musaceae (Cheesman 1947). Geographically distributed as a wild species in Sub-Saharan Africa and Asia (Simmonds 1962), enset is cultivated only in its native Indigenous farming systems in Ethiopia. Morphologically, it is very much like a banana. But, unlike bananas, enset is instead the swollen pseudostem base, leaf sheaths, and underground corm that provide a year-round dietary starch source (Borrell et al. 2019; Tesfaye and Ludders 2003). Enset is a recognized multipurpose plant, providing a range of services for farmers such as food, forage, fiber, medicine, construction, and soil protection (Haile, Tesfaye and Olango 2022; Tesfaye and Ludders 2003). Enset is the most important food crop in Ethiopia, where it serves as a staple and co-staple food for an estimated 10 to 15 million people (Tefaye and Ludders 2003; Tesfaye 2008a). Enset farming system is regarded as one of the few ancient and sustainable agricultural systems in Africa (Westphal 1975). Enset can tolerate prolonged periods of drought and is hence considered a priority crop in Ethiopia to food security.

Ethnobotanical studies will be highly important for genetic improvement and conservation of valuable crops. Earlier studies indicate that a wide range of enset diversity exists in Ethiopia (Borrell et al. 2019; Gerura et al. 2019; Haile, Tesfaye and Olango 2022; Negash 2001; Olango et al. 2014; Robi, Negussie and Tetemke 2019; Shigeta 1990; Tesfaye 2008a, b; Tesfaye and Ludders 2003; Tsegaye and Struik 2002). Among others providing information in this regard, Tesfaye and Ludders (2003) and Olango et al. (2014), respectively, reported 86 and 67 named enset landraces from Sidama and Wolaita areas of Southern Ethiopia. More recently, Haile, Tesfaye and Olango (2022) reported 123 enset landraces from Sheka areas of Southwestern Ethiopia. Most of the locally recognized landraces are consistent to a substantial extent with the variability obtained by molecular diversity studies (Gerura et al. 2019; Negash et al. 2002; Olango et al. 2014). Most of these findings clearly indicate that the landrace diversity of enset appears to be related to the culture, knowledge, and practices of the different ethnic groups.

This paper presents the folk nomenclature and taxonomy of enset that was used by the Kafficho people, who are residents of Kaffa in Southwest Ethiopia. Preliminary reports in Kaffa and its environs showed that a great wealth of enset diversity is still maintained as landraces by a traditional farmer (Haile, Tesfaye and Olango 2022; Negash 2001; Negash et al. 2002; Robi, Negussie and Tetemke 2019). However, some of these reports were limited to a specific growing region within a few ethnic groups, or focused on genetic diversity studies without addressing ethnobotany of folk cultivars. Accounts on the role of folk nomenclature and taxonomy as a means to maintain diversity have not been well studied for enset in Kaffa. It is obvious that a thorough understanding of such aspects is a key to comprehending how this diversity is perceived and valued by farmers. The insight that this study provides is valuable for the improvement and conservation of enset in Southwest Ethiopia, in particular, and in Ethiopia at large. Keeping in view all these points, this study was conducted

with the objectives to investigate the folk wisdom of identifying, naming, and classifying enset landraces by the Kafficho farmers and to assess the role of folk nomenclature and taxonomy as a means to maintain diversity.

## Methodology

### Description of Study Area

This study was conducted in the Kaffa Zone. Keffa or Kaffa, is a Zone in the Southwest Ethiopia region. Kaffa Zone is subdivided into 17 districts and its administrative center is Bonga. Based on the Central Statistics Authority (CSA) population projection values, this Zone has a total population of 1,029,807 of which 911,896 (89%) are rural inhabitants (CSA 2013). Kaffa Zone is well-known for its multi-ethnic diversity; with the dominant ethnic groups include the Kafficho (82.72%), the Bench (5.05%), the Amhara (3.67%), and the Oromo (3.5%). The remaining ethnic groups made up 5.09% of the population. Figure 1 presents a map of the study area, indicating the surveyed points in Kaffa Zone.

### The Kafficho People

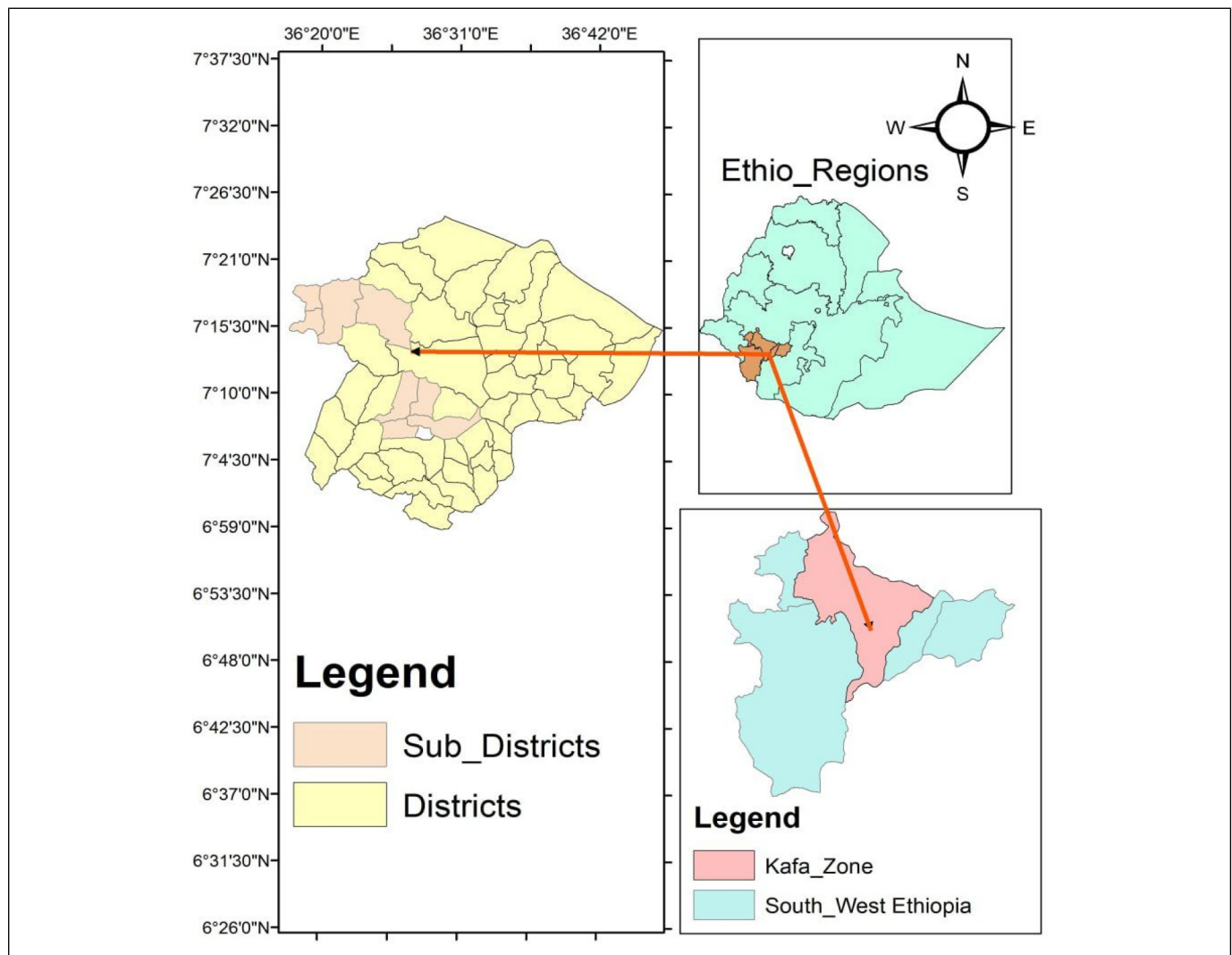
Kafficho is the name referring to the inhabitants of Kaffa in Southwest Ethiopia who speak Kaffi-Noono language. The language of the Kaffa is classified and named as Omotic (Fleming 1976). In the same Omotic cluster, the Sheka, the Sheko, the Bench, the Dizi, and others were classified by Fleming (1976) as western Omotic. Culturally the Kafficho people are closely related to Bosha (Garó), Enarya (Hinnaro), Anflo (Bushashe), Sheka, and Shinasha (Boro), which are all put under the umbrella of Gongga (Bekele 1996).

### Enset Farming and Other Cropping Profile

Enset is one of the most important staple food crops of the people. In the entire region, where cultivation of enset is ecologically feasible, the Kafficho enset farming and their historical focus on it is unique. They had the oldest of old domestic enset gardens, a long-time history of cultivation, and a culture of utilization that extends beyond the written history. Sundry wild enset forests also exist in close proximity to cultivated enset gardens. They are also practicing mixed crop–livestock production and are known for their customary forest-based farming systems. Coffee, cereals (maize, wheat, and barley), fruits (banana, papaya, mango, and avocado), and spices (coriander, ginger, pepper, turmeric, and hell) are widely cultivated. Others such as lowland rice, hell, black pepper, cassava, tea, and rubber tree grow successfully in this Zone.

### Data Collection Procedure

Data were collected during 2022/2023 by combining methodologies for the acquisition of indigenous knowledge, including



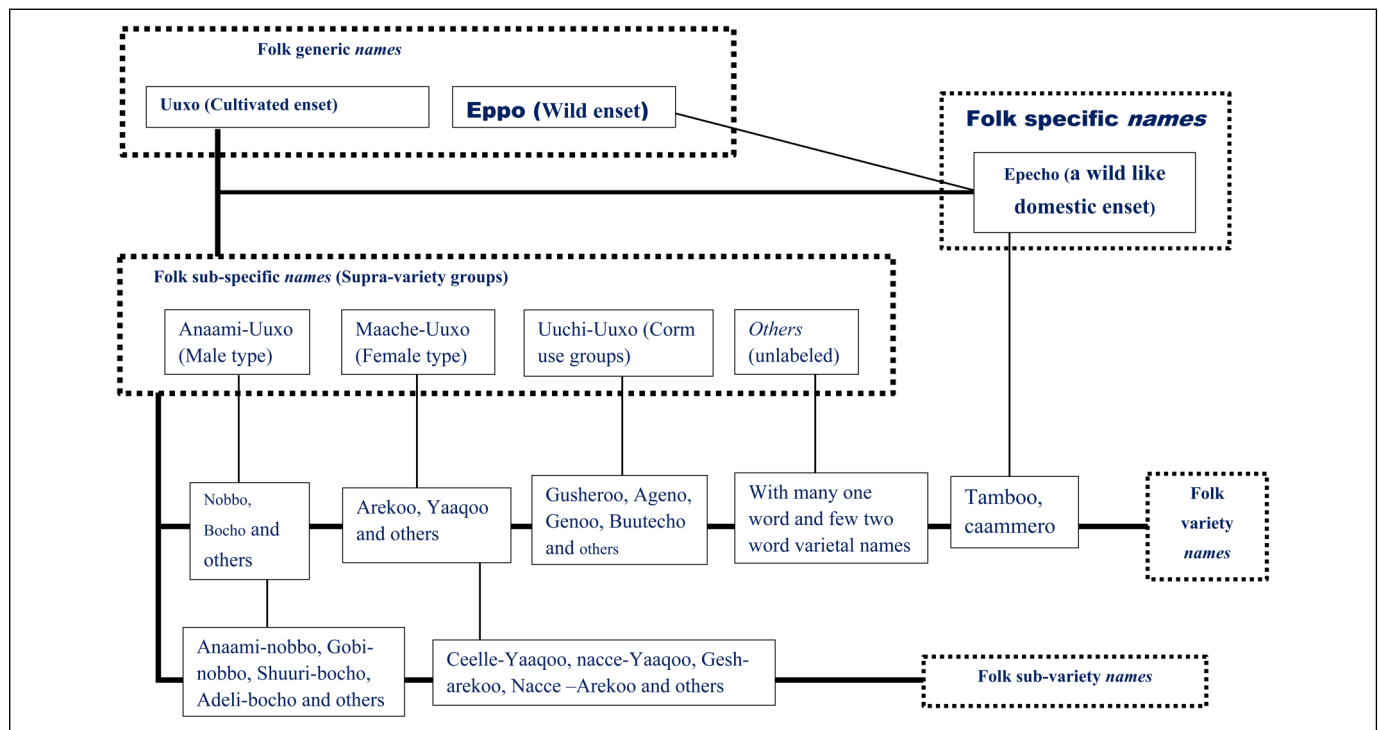
**Figure 1.** Map of the study area, Kaffa zone.

literature review and Participatory Rural Appraisal (PRA) tools (individual interviews, focus groups, and direct observations). Enset growing farmers were purposively considered for this survey. A total of two enset growing districts namely, Tello and Adiyo districts of Kaffa Zone were considered in this study. Within these districts informal survey was conducted to identify enset farming sub-districts. Afterward, eight predominantly enset growing sub-districts were selected. There were 240 randomly selected households that were considered as an overall sample size for the study. We chose 30 households from each sub-district for individual interviews. The data collection procedures for the inherent subsystems of Indigenous biosystematics are summarized as follows:

Folk classification was studied with the use of participant interviews, researcher observations and comparison of farmers-recognized taxa with formal taxonomy. By detailing the folk taxonomic systems of enset in Kaffa, the folk ranks have been suggested by the authors as per the universal scheme

proposed by Berlin, Breedlove and Raven (1973) and Berlin (1992). Accordingly, at least four, perhaps five folk taxonomic categories can be recognized in Kaffa. The following types of questions were asked to participants. First, farmers were asked about the names and characteristics of higher ranks (generic names) to all kinds of ensets that they knew. Categories satisfying these conditions were labeled as generic by the authors. Second, farmers were asked to list the names and characteristics of some specific groups (unique types) of domestic ensets that they grew or knew. Groups satisfying these conditions are specific; their labels are specific names.

Third, farmers were asked to free list the names of individual varieties (both known and actually grown) that they perceive as a distinct unit. Categories satisfying these conditions were labeled as varietal. Farmers also recognize a sub-category within the varietal category. The sub-category of a variety has been labeled as a sub-variety by the authors. Lastly, during the survey, we recognize additional ways of traditional



**Figure 2.** Schematic representation of hierarchical folk taxonomic systems of enset as commonly used by the Kafficho people.

groupings that assemble several varieties and sub-varieties together based on contexts of the plant, sex, and use value. We therefore include one additional category in between varietal and specific ranks. Groups satisfying these conditions were labeled as sub-specific (supra-variety). Figure 2 provides a hierarchical scheme of folk taxonomy applied for enset, as commonly used by Kafficho farmers.

Folk nomenclature and descriptors were recorded according to the procedure indicated by Haile, Tesfaye and Olango (2022) and Worojie, Asfaw and Mengesha (2021). Folk nomenclature was analyzed using a basic ethnolinguistic analysis, i.e., questions concerning the inherent logic and etymologies of folk names were recorded with the use of farmers' interview and researcher observations. Individual farmers were asked to free list the local names of enset varieties and sub-varieties that they grew or knew. All the folk names were registered and translations considering meaning, origin and structures of folk names were made with the use of elderly farmers. Individual lists were then merged to produce a composite list. Folk descriptor was studied based on the farmer-free listing of individual taxa along with their descriptors; according to participants own order of priority without major researcher intervention. Participants were asked to free list the names of (both known and actually grown) individual taxa. For each of the names, farmers were asked how they are able to identify it. All the folk descriptors were registered and supplemented with field observation by the researcher to verify the information gathered.

## Results

### Folk Taxonomy

By detailing the folk taxonomic systems of enset in Kaffa, the authors have suggested the folk ranks as per the universal scheme proposed by Berlin, Breedlove and Raven (1973) and Berlin (1992). Accordingly, the folk taxonomic systems stated in the Kaffa area show a pattern of hierarchy, beginning at the folk generic level and descending to the level of sub-variety. It allows for the recognition of at least four, perhaps five, folk taxonomic ranks. The taxa assigned to each group are perceived as distinct and arranged hierarchically. In order from the most inclusive to the least inclusive group, the categories are folk generic, folk specific, folk sub-specific (supra-varieties), folk variety, and folk sub-variety (Table 1). The Kafficho commonly and widely used the term *Uuxo* to distinguish the genus *Ensete*, which the enset plant belongs to, from *Muuzo*, a morphologically similar plant in the genus *Musa*. This generic name is employed to label all the cultivated enses grown in Kaffa. Thus, on the level of folk genus, all the domestic enses have been merged into the Kaffa concepts of “*Uuxo*,” while they knew the wild enset by the folk generic name of *Eppo*.

On the level of folk species, the Kaffa differentiated a few cultivar groups of bitter enses (such as *Epecho*, *Tamboo*, and perhaps *Caammero*) from the non-bitter enses (*Uuxo*). The term *Epecho* is frequently used to describe all the cultivar

**Table 1.** Kaffa Botany of Enset in Relation to Standard Illustrations in Ethnobotanical Classification (Berlin, Breedlove and Raven 1973; Berlin 1992).

Folk taxonomic groups using standard illustration	Kafficho label	Number of identified taxa	Naming structures applied to individual names
Folk generic	<i>Eppo, Uuxo</i>	2	Unitary names
Folk specific	<i>Epecho</i>	2	Unitary names
Folk sub-specific (supra-variety groups)	No names as a general category	9	Unitary names, with few (3) binary names
Folk variety	Unlabeled	95	Unitary names, with few (7) binary names
Folk sub-variety	Unlabeled	31	Binomial names

groups of bitter domestic ensets. Below the folk-specific level, the *Uuxo* and *Epecho* groups divide into a number of locally named varieties. The former has up to 92 named varieties of enset in Kaffa, whereas the latter has only 3. The lowest rank in Kaffa folk taxonomy of enset is that of sub-variety (subordinate units within the variety). Seven varieties have sub-varieties, varying from 2 to 9. Kaffa botany of enset recognizes around 126 named, perhaps distinct units of enset at intraspecific levels (Tables 2 and 3).

### Folk Nomenclatures

The folk nomenclature system in the Kaffa area was analyzed and it was found that the individual units are grouped into three locally recognized groups. These include variety, sub-variety, and supra-variety groups. The local system employed for naming and identification of taxa assigned to the three groups are described below.

### Names and Naming of Enset Varieties

The Kaffa farmers have identified around 95 named enset varieties. Of these, 51 represent actual grown varieties of enset. Besides, 12 additional varieties that were actually grown were found in farms of non-sampled households, while the rest were reported verbally. Each of these is perceived as distinct and given a separate name. The lists of names of enset variety recorded in Kaffa together with their implied etymology and meanings are presented in Table 2. Names of varieties are derived from a wide range of sources. The bases from which names are sourced include geographic origin, plant morphology, as well as attributes, or name of social groups, objects, or animals. For instance, names such as *Argamoo*, *Cito*, *Gemiro*, *Hecewo*, *Mattecho*, and *Mocho* may be derived from the names of a tribe/clan. In addition, there are various names; for example, *Adiyo*, *Bongoo*, *Boxoo*, *Canno*, *Korimoo*, and *Caagecho* are related to place of origin or

area name and names such as *Arekoo*, *Bajjoo*, *Maacaa-Damoo*, and *Gusheroo* are referring to plant characters. Others may indicate the name or features of trees (e.g., *Yudaafso*, *Yaabecho*, *Qoreddo*, *Oomo*, *Gayoo*, and *Buutecho*), name of objects (e.g., *Ageno* and *Chooro*), or likeness of other crops (e.g., *Officho* and *Kecoo*). Translation of names showed that about 66% of the variety of names have meanings, while the rest have no meanings, or their etymology is lost (Table 2).

Analysis and interpretation of the labels applied for the naming of enset varieties showed that they are of two types structurally. These are unitary and binary names. Unitary/uninominal names are those names that are composed of a single word while those that consisted of two words are called binary/binomial names. Eighty-eight (93%) of the varieties recorded in Kaffa are labeled with uninominal names whereas the names of seven (7%) varieties are binary; indicating that variety labeling structure in Kaffa is skewed to uninominal. Examples of unitary names include *Adiyo*, *Ageno*, *Arekoo*, *Bajjoo*, *Bocho*, *Nobbo*, etc. Examples of binary names include *Coora-Qaayo*, *Maacaa-Damoo*, *Maach-Koto*, and *Qocce-Taattoo* (Table 2).

### Names and Naming of Enset Sub-Varieties

Kaffa botany of enset recognizes a sub-category within the varietal category. The authors have designated the sub-category of a variety as sub-variety. Altogether 31 sub-varieties are recorded in Kaffa. Of these, 19 (61%) were actually grown sub-varieties while the rest were reported verbally. The naming structures used in Kaffa for labeling sub-varieties show that they all consisted of two words (Table 3). The basic name of a sub-variety is thus a binary name. Earlier, it was also shown that the names of some enset varieties are binary. Both binary names of a variety and a sub-variety consisted of two words. The two, however, differ in that a binary name of a sub-variety consists of the name of a well-known enset variety plus a modifier, or an adjective that describes the specific characteristics of a sub-variety.

Examples of a well-established enset variety to which the sub-variety belongs include *Bocho*, *Nobbo*, *Arekoo*, *Bajjoo*, *Manjiyo*, *Yaaqoo*, and *Epecho*. Generally, the most widely grown enset varieties have more sub-varieties. Therefore, *Bocho*, *Nobbo*, and *Arekoo*, the most widely grown varieties in Kaffa, with each having nine, six, and five sub-varieties, respectively, while the rest have between two and four. About 61% of the sub-variety names consist of the name of a well-known variety plus a prefix that describes the pseudo-stem color of a sub-variety, such as aa'i "black," ceelle "red" and nacce "white." Other prefixes added to the main variety names may indicate the name of a clan (e.g., *Adeli-bocho* and *Shuuri-bocho*), name of animals (e.g., *Akke-bocho* and *Machi-bocho*), geographic origins (e.g., *Ganji-bocho*, *Gesh-arekoo*, *Kafi-bocho*, *Yahi-bajjoo* and *Gobi-nobbo*), or sex of the subordinate units (e.g., *Anaami-nobbo* and

**Table 2.** Lists, Word Origin, and Meaning of Names of Enset Varieties Recorded in Kaffa.

No.	Name of varieties	References	Sex	Origin of names	Meaning of names
1	<i>Aachecho</i>	1, 2	F	Plant sap nature	A name means watery.
2	<i>Adiyo</i>	1	M	District name	Name after place of Adiyo in Kaffa
3	<i>Ageno</i>	1	M	Name of object	Names means moon in Kaffa
4	<i>Aaki-baroo</i>	1, 2	M	Name of animals	A giant bird in Kaffa
5	<i>Arekoo</i>	1, 3	F	Plant characters	Name means stunted
6	<i>Argamoo</i>	1	M	Social groups	Argamoo, clan name in Kaffa
7	<i>Badaadoo</i>	1	M	Others	Name means stranger person
8	<i>Bajjoo</i>	1, 2, 3	M	Plant characters	Enset with bending pseudo stem
9	<i>Bakamo</i>	1, 2	—	—	—
10	<i>Besanoo</i>	2	—	—	—
11	<i>Bocho</i>	1	M	Others	A large or big object
12	<i>Bomboo</i>	4	—	—	—
13	<i>Bongoo</i>	1, 2	—	Name of place	Name after the place Bonga in Kaffa
14	<i>Boxoo</i>	1	M	Name of place	Name after the place Boxi in Kaffa
15	<i>Bumboo</i>	1, 2	—	—	—
16	<i>Buutecho</i>	1	M	Name of tree	Butoo, a large tree of <i>Ficus</i> spp. in Kaffa
17	<i>Caaggecho</i>	1	F	Name of place	Names after a place Cagga found in Adiyo district
18	<i>Caagoo</i>	1	M	Name of tree	Caggoo, a type of big tree
19	<i>Caammero</i>	1	M	Taste of corm	Bitter
20	<i>Cammo</i>	1	M	Texture of corm	Hairy
21	<i>Canno</i>	1	M	Name of place	Name after place of Chena in kaffa
22	<i>Chikero</i>	1, 2	—	—	—
23	<i>Chooro</i>	1, 2	F	Name of object	Chooro, Sunlight in Kaffa
24	<i>Cito</i>	1	M	Social groups	Name of a clan, cito
25	<i>Congoo</i>	1, 5	—	—	—
26	<i>Coora-Qaayo</i>	1	F	—	Name refers to eaten with meat
27	<i>Dabi'o</i>	4	—	Plant name	dabi'e sheqee, variety of barley in kaffa
28	<i>Deeki</i>	2	—	—	—
29	<i>Eenno</i>	1	F	—	—
30	<i>Epecho</i>	1	M	Other	Epecho, wild like domestic enset.
31	<i>Ferenjecho</i>	1	—	Skin Color	White
32	<i>Gabeti</i>	1, 2, 5	—	Plant characters	White pseudo-stem
33	<i>Garamanji</i>	1, 2	—	Name of place	<i>Garamanji</i> , place name in Kaffa
34	<i>Gatenoo</i>	1	M	Name of animal	Gattoo means oxen
35	<i>Gayeno</i>	1	—	—	—
36	<i>Gayoo</i>	1	F	Tree name	Gayoo, thin and long tree
37	<i>Gemiro</i>	1	M	Social group	<i>Gemiro</i> , name of clan in Kaffa
38	<i>Genoo</i>	1	F	Sex groups	Genno, another name of female enset in kaffa
39	<i>Ginkayo</i>	2	—	—	—
40	<i>Goomijjo</i>	1, 2, 5	M	Plant characters	Names means hard
41	<i>Gooshido</i>	1, 5	M	—	—
42	<i>Goshno</i>	1, 2, 5	F	—	—
43	<i>Gudich</i>	4	—	Name of animal	Gudino, means swine in Kaffa
44	<i>Gusheroo</i>	1	F	Plant characters	Enset with fat pseudo stem at the base.
45	<i>Hicewo</i>	1	F	Social groups	Name of clan in Kaffa
46	<i>Kalloo</i>	1	M	—	—
47	<i>Kachichi</i>	1, 4	M	Name of shelter	Name refer house (kexo) in Kaffa
48	<i>Katino</i>	1, 2	F	—	—
49	<i>Keboo</i>	2	—	—	—
50	<i>Kecoo</i>	1	F	Name of plant	Kecee, name of a variety barley in kaffa
51	<i>Kekero</i>	1, 2	—	—	—
52	<i>Ketano</i>	1, 2	F	—	—
53	<i>Kophir</i>	1, 2	—	—	—

(continued)

**Table 2. (continued)**

No.	Name of varieties	References	Sex	Origin of names	Meaning of names
54	<i>Kopicho</i>	1, 2	—	—	—
55	<i>Korimoo</i>	1, 2	—	Place name	Name after a place of korimoo
56	<i>Maaca-Damoo</i>	1, 3	F	Plant characters	Red sap color resulting to reddish kocho color
57	<i>Mach-Koto</i>	1, 4	—	Plant name	Name refers garden plant (used as relax)
58	<i>Madii</i>	2	—	—	—
59	<i>Manjiyo</i>	1	M	Plant characters	Name means hard enset
60	<i>Mattecho</i>	1	M	Social groups	Name of a known a clan in Kaffa, Matto
61	<i>Mishiko</i>	1	—	—	—
62	<i>Mocho</i>	1, 2	—	Social groups	Mocho, name of a known a clan in Kaffa
63	<i>Nobbo</i>	1	M	Other	Nobbo, virgin land
64	<i>Officho</i>	2, 4	—	Other	Name refers grown with Ofiyo (kororima)
65	<i>Omichi</i>	2, 4	—	—	—
66	<i>Oomo</i>	1, 2	M	Tree name	Name of a large tree Oomo
67	<i>Qattaano</i>	1	M	—	—
68	<i>Qattoo</i>	1	M	Name of tree	A large evergreen tree in Kaffa
69	<i>Qocce-Taattoo</i>	1	M	Other	Names refers to a king of kocho
70	<i>Qoreddo</i>	1	F	Plant characters	Qoreddo means cloth like large leaves
71	<i>Shallakoo</i>	1	M	—	—
72	<i>Shangoo</i>	1	F	—	—
73	<i>Shatakoo</i>	2	M	—	—
74	<i>Shido</i>	1, 3	F	Social groups	Shido, name of clan in Kaffa-Sheka
75	<i>Shiiqo</i>	1	F	—	—
76	<i>Shimo</i>	1, 2, 3	F	Plant physiology	Names means mature
77	<i>Shodoodino</i>	1	F	—	—
78	<i>Shoto</i>	1	M	Other	Name refers to a big enset (woyee Ooge uuxo)
79	<i>Shuuri</i>	2, 3	F	Social groups	Name of clan, Shuuro
80	<i>Tambo</i>	1	M	Other	Wild like domestic enset
81	<i>Tarelo</i>	2	—	—	—
82	<i>Tayo</i>	1, 2	F	—	—
83	<i>Teeno</i>	1	M	—	—
84	<i>Utino</i>	1	F	Other	Name refers to testy Enset (occoo shaawo)
85	<i>Utiro</i>	1	F	—	—
86	<i>Waaaji-Belli</i>	2	F	—	—
87	<i>Wangoo</i>	1, 2, 3	F	Name of animal	Fox species
88	<i>Wu'oo</i>	1	F	Other	Wu'oo means to a big rope in Kaffa
89	<i>Wu'roo</i>	1	F	Other	Name refers to fast growing enset
90	<i>Yaabecho</i>	1	F	Name of tree	Yaaboo/yahoo, types of big tree in Kaffa
91	<i>Yaaboo</i>	1	F	—	—
92	<i>Yaahoo</i>	1	F	—	—
93	<i>Yaaqoo</i>	1	F	—	—
94	<i>Yeshankila e.</i>	2	M	Social groups	Shankila, color of clan in Kaffa
95	<i>Yudaafu</i>	5	—	Other	Seed of flowered plant.

Note. F-refers to Female, M refers to Male, 1 = the present study, 2 = Negash (2001), 3 = Haile, Tesfaye and Olango (2022), 4 = Bonga in situ conservation site (2006), 5 = Woldegebriel (2019)

*Maache-nobbo*) (Table 3). Each is recognized as distinct from all the others and the main variety, at least in one feature, since each carries a modifier describing the subordinate units.

### Supra-Variety Categories

Kaffa farmers have a number of other systems for grouping enset landraces. Three major types of groupings can be

recognized based on cultivation contexts, gender, and utilization. Each of these groupings is formed by assembling several varieties and sub-varieties together; they are thus supra-variety categories, i.e., are groupings higher than the folk variety. The different supra-variety groups exhibit a number of distinct features that mark them from one another. Yet, such groupings are not always mutually exclusive and some share a few attributes in common. Table 4 presents a description

**Table 3.** Lists of Sub-Variety Names Recorded in Kaffa together with the Main Variety to which the Sub-variety Belongs.

No.	Name of varieties	Name of sub-varieties	References	Sex	Meaning and origin of names or the underlying basis of folk classification
1	Arekoo	<i>Aa'i-arekoo</i>	1, 2	F	The prefixes 'aa'i', 'ceelle' and 'nacce', respectively are refer to black, red and white pseudo-stem.
2		<i>Ceelle-arekoo</i>	1, 2	F	
3		<i>Nacce-arekoo</i>	1, 2	F	Names refers to its origin, Gesha
4		<i>Gesh-arekoo</i>	2	F	
5		<i>Tuti-arekoo</i>	2	F	
6	Bajjoo	<i>Aa'i-bajjoo</i>	1	M	Color of the pseudo-stem (black).
7		<i>Ceelle-Bajjoo</i>	1	M	Reddish pseudo-stem
8		<i>Nacce -Bajjoo</i>	1	M	Color of the pseudo-stem (white).
9		<i>Yahi-Bajjoo</i>	2	M	Name refers to its origin, Yaha
10	Bocho	<i>Aa'i-bocho</i>	1	M	Color of its pseudo-stem, blackish.
11		<i>Adeli-bocho</i>	1	M	Name refer Adelo clan in Kaffa
12		<i>Akke-bocho</i>	1	M	Names originated from the name of animals, which means a bird means Akkee in Kaffa
13		<i>Ceelle-bocho</i>	1	M	Have Reddish, pseudo-stem
14		<i>Ganji-bocho</i>	1	M	Names refers to a place in kaffa (Gaanji)
15		<i>Kafi-bocho</i>	1	M	Name refer the name of a known a clan in Kaffa
16		<i>Maci-bocho</i>	1	M	Names originated from the name of animals, which means a horse means Maco in Kaffa
17		<i>Nacce-bocho</i>	1	M	Whitish pseudo-stem
18	Epecho	<i>Shuuri-bocho</i>	1		Name refer the name of a known a clan in Kaffa
19		<i>Ceelle-Eppo</i>	1, 5	M	Possess reddish pseudo stem
20		<i>Nacce-Eppo</i>		M	Color of the pseudo-stem (white).
21	Manjiyo	<i>Aa'i-Manjiyo</i>	1	M	Have pseudo-stem with black strap
22		<i>Ceelle-Manjiyo</i>	1, 5	M	Color of the pseudo-stem (red).
23		<i>Nacce-Manjiyo</i>		M	Have whitish pseudo stem
24	Nobbo	<i>Aa'i-nobbo</i>	1	M	Color of the pseudo-stem (black).
25		<i>Anaami-nobbo</i>	2	M	Name <i>anaami</i> means male in Kaffa
26		<i>Ceelle-nobbo</i>	1	M	Have reddish pseudo stem
27		<i>Gobi-nobbo</i>	1, 2	M	Name refers to the name of place in Kaffa, known as Goba
28		<i>Maache-nobbo</i>	1	F	Name <i>maache</i> means female in Kaffa
29		<i>Nacce-nobbo</i>	1	M	Color of the pseudo-stem (white).
30	Yaaqoo	<i>Ceelle-Yaqoo</i>	1	F	Color of its pseudo-stem, reddish.
31		<i>Nacce-Yaqoo</i>	1	F	Color of the pseudo-stem (white).

of some nine supra-variety groups that are common in Kaffa. The characteristics of the different groups and the basis of the farmer's classifications are presented below.

### Grouping on the Basis of Cultivation Contexts

On the basis of cultivation contexts, two main supra-variety groups can be identified: wild and cultivated ensets. The "wild" group here refers to ensets that are growing wild in the forest and have no known history of human manipulations. Such enset types are known in Kaffa as *Eppo* as a general category, with different one-word names for smaller categories. Additionally, some farmers referred to the *Eppo* as "*kocho-seytanoo*," which means that it belongs to the devils. According to the farmer, the product turned into black instantly after scraping; which makes it unattractive to eat. It also has a

bitter taste while eating; farmers therefore believe that it causes death if consumed. Hitherto, it is not poisonous and can be consumed if a need arises. Its unsuitability for consumption is thus up to farmers' beliefs. The suffix "*seytanoo*" has nothing to do with the devil; instead, it has a bearing on the location where it grows.

Farmers divide the cultivated groups into two sub-groups: the first sub-group contains a few groups of bitter domestic ensets. We thus label this supra-variety group as "*a wild like domestic enset*." Such enset types are known as *Epecho* in Kaffa as a general category. The second sub-group includes a well-known and longtime cultivar group of non-bitter domestic ensets. They are usually grown in home gardens, which are located around, or near the resident house. We label this supra-variety category as a cultivar group of cultivated enset. In Kaffa, such enset types are collectively known as "*Uuxo*" (Table 4).



**Table 4.** Intermediate Folk Groups (Sub-Specific/Supra-Variety Categories) of Enset in Kaffa.

Folk basis	Categories	Kafficho label	Characteristics of each category as described by local farmers plus number of varieties and sub-varieties recorded in each group	
Context	Wild	<i>Eppo</i>	Grow wild in the forest. The product turned into black and has a bitter taste. It is considered as non-edible.	0 (0)
	Wild like domestic enset	<i>Epecho</i>	Grows in home garden and is said to be edible. But, it is as bitter as the wild types.	3 (2)
	Cultivated	<i>Uuxo</i>	They are edible and are non-bitter. Named and described and occurs in home garden under farmers' management.	92 (29)
Gender	Male	<i>Anaami-Uuxo</i>	Late maturing, drought and disease resistant, strong and vigorous growth, low to moderate <i>Qocco</i> and <i>Ettino</i> quality, high fiber strength, medium to large pseudo-stem size and height, mostly have non-edible corms, and high yield.	33 (23)
	Female	<i>Maache-Uuxo</i>	Early maturing, susceptible to drought and disease, thin and less vigorous, high <i>Qocco</i> and <i>Ettino</i> quality, moderate fiber strength, small to medium pseudo-stem size and height, and low in yield with edible and tasty corm	32 (8)
Use value	Corm use groups	<i>Uuchi-wuxoo</i>	Those whose corm can be dug and eaten after boiling. A few male and most female types are preferred.	21 (6)
	Processing groups	<i>Kocho</i> ( <i>Qocco</i> )	It is a traditional food prepared by fermenting the pulp derived from scraped leaf sheaths and grated corms	95 (31)
		<i>Bulla</i> ( <i>Ettino</i> )	<i>Ettino</i> is a local food prepared by squeezing out of the crude starch from leaf sheaths and corms. Most female types and some male types are in this category	36 (7)
	Medicinal/ritual use groups	Unlabeled	The starchy powder, boiled corms, uncooked true stems, or leafs of enset may be used for these purposes	6 (0)

Note. Values in parenthesis are number of sub-varieties ( $N = 31$ ); values without parenthesis are the number of varieties ( $N = 95$ ).

### Grouping on the Basis of Gender

On the basis of gender, landraces of enset fall into two supra-variety groups: male (*Anaami-Uuxo*) and female (*Maache-Uuxo*). Of the enset varieties recorded in Kaffa, 33 (35%) are male and 32 (34%) are female. Evidence is not available regarding the sex of the remaining varieties (Table 2). Likewise, 23 (74%) sub-varieties are male, while the rest are female (Table 3). Since enset is a bisexual plant (Cheesman 1947), farmer's distinction as male/female has nothing to do with the biological sex of the plant, instead it has a bearing on the different qualities favored by men and women. According to the related custom in Kaffa-Sheka, it also has a bearing on the society's perception of gender and its role. For example, the male type is big, vigorous, strong, and tolerant to environmental stress. This habit appeared to reflect the qualities preferred by men and/or seemed to reflect what is expected of a man in society. The female type enset, on the other hand, is early maturing and has high *Kocho* and *Ettino* quality (i.e., are local foods made from enset) (Table 4). This dichotomy appeared to reflect the qualities favored by women across Kaffa. A list of examples of male and female varieties and sub-varieties of enset growing in Kaffa are presented in Tables 2 and 3.

### Grouping on the Basis of Use Value

On the basis of utilization: enset varieties and sub-varieties fall into three main supra-variety groups: these are corm use groups,

processing groups, and medicinal/ritual use groups. The corm use groups are those whose corm (*Amicho/Uuchi-wuxoo*) can be dug and eaten after boiling. Some 21 varieties and 4 sub-varieties of enset are included in the corm use groups (ESM 1). The Kafficho divide the processing groups into two sub-groups: (1) those that require complex processing (i.e., decortating of leaf sheaths and grating of corms and allowing fermentation of the resulting pulp into the local foods known as *kocho/Qocco*) and (2) those that require complex processing, but no fermentation (i.e., squeezing out the liquid from scraped leaf sheaths and grated corm and allowing the resultant starch to concentrate into white powder known as *bulla/Ettino*). The processing group for *Qocco* includes all of the varieties and sub-varieties recorded in Kaffa. On the other hand, all those varieties and sub-varieties listed in the corm use groups together with some fifteen additional varieties listed in ESM 1 are favored for *Ettino* processing.

The other category recognized by the Kaffa people on the basis of utilization is that of the medicinal/ritual use groups. Six enset varieties namely *Chooro*, *Coora-qaayo*, *Tayo*, *Maacca-Damoo*, *Waajji-Belli*, and *Arekoo* are included in the medicine/ritual use groups (ESM 1). The boiled corm of *Maacca-Damoo* and *Chooro*, for instance, is mixed with butter and milk and is fed to a woman right after delivery of the baby to stimulate the discharge of the placenta. The starchy powder or the boiled corm of *Tayo* is consumed to cure sicknesses, such as displacement of joints and bone fractures. The true stem of *Arekoo* is fed to children, uncooked, to keep the children healthy and to help them gain weight.

According to the farmer, *Chooro* has a ritual importance and they said that all the devil or evil spirits will go away if they plant this variety in their garden.

### Folk Descriptors

Kaffa botany of enset is based on a large number of folk descriptors. Altogether 22 characters and 86 character states were used by the Kafficho farmers as keys to discriminate one taxon from another taxon. The folk descriptors used by farmers for identification of varietal and sub-varietal taxa are presented in Electronic Supplemental Material 1 (ESM 1).

The determination of a variety's identity and distinctiveness is made by considering a large number of plant morphological and physiological characters, use-related traits, and other non-plant characters. More than half of these refer to aspects of a variety's morphology, thus showing that morphological characters played a key role in the local distinction of enset varieties. Of these, color, height, and size of pseudo-stem, and midrib and petiole colors played a key role in the local identification of varieties. Major physiological characters by which farmers used to distinguish the enset varieties were sucker regeneration rate, time to maturity and response to drought and disease. Moreover, product-related characters such as utilization of corms, food value (kocho and ettino content and quality), fiber strength, and medicinal values are used by farmers to distinguish their enset varieties (ESM 1).

The different sub-varieties of a given variety were reported to have the diagnostic features of the main variety; each was also reported to differ from all the others and the main variety at least in one feature. One sub-varietal category differs from another in pseudo-stem colors (Table 3 and ESM 1). We identified nineteen (61%) sub-varieties carrying prefixes linked to the specific plant characteristics (e.g., aa'i "black," nacce "white," and ceelle "red"). Five (16%) sub-variety names carry prefixes that refer to geographic origins; while the rest of the names carry modifiers that reflects the name of a clan, or animals.

### Discussion

The folk taxonomy of enset in Kaffa consists of five levels that are arranged in a hierarchy. In order from the most inclusive to the least inclusive groups, the categories are folk generic, folk specific, folk supra-variety, folk variety, and folk sub-variety. At folk generic level, the Kaffa recognize two well-defined taxa of ensets: *Uuxo* (cultivated enset), and *epo* (wild enset). The wild enset does lack folk specific taxa, but *Uuxo* has a limited number of folk-specific and a large number of folk intra-specific taxa. The main differentiating criterion between the folk generic taxa is based on the suitability for consumption and places where they are grown. Our result is in accord with earlier reports on enset and yam in Ethiopia (Haile, Tesfaye and Olango 2022; Hildebrand 2003; Tesfaye 2008b; Worjje, Asfaw and Mengesha 2021) and on potato in the Andes

(Brush 1992; Brush, Carney and Huamán 1981; Haan et al. 2007; Zimmerer 1996), where the local farmers in each of these areas recognize the folk generic taxa in a similar way.

In Kaffa, enset is represented by a large number of intraspecific units. Altogether 126 named landraces (95 varieties plus 31 sub-varieties), including those found in non-sampled farms was recorded in this study. Kaffa farmers have more named enset landraces than previously reported in Ethiopia (Haile, Tesfaye and Olango 2022; Negash et al. 2002; Tesfaye 2008b; Tsegaye and Struik 2002). The large number of enset landraces recorded reflects the existence of considerable diversity within the crop and the long history of its cultivation in Kaffa and its environs. Yet, only 65% of these landraces are actually grown in Telo and Adiyo districts while the rest reported verbally. Most of the verbally reported landraces were never encountered during the survey, indicating that some of the Indigenous enset types are abandoned. The rich folk nomenclature, on the other hand, is a clear indicator of Kaffa farmers' heavy reliance on enset. Heavy reliance on a single crop has been associated with the maintenance of diverse landraces (Hames 1983). This completely agrees with the idea of Boster (1985), Brush (1992), Quiros et al. (1990), and Zimmerer (1991) that folk taxonomy of great intraspecific variability can be understood as a means to maintain diversity and that diversity is sought for its own sake and not for a specific reason.

Comparisons between formal and folk taxonomic systems show a modest overlap. Among others, in Kaffa botany of enset, intraspecific taxa occur in contrast set of large numbers. Such large intraspecific variability is rare and is often related to crops of great socio-cultural importance (Berlin 1992; Berlin, Breedlove and Raven 1973). A similar distinction has been made for enset (Haile, Tesfaye and Olango 2022; Negash 2001; Shigeta 1990; Tesfaye 2008b), for yam (Worjje, Asfaw and Mengesha 2021) and for sorghum (Mekbib 2007) in Ethiopia. On the other hand, molecular studies have shown the existence of a considerable correspondence between folk and biologically recognized groups (Gerura et al. 2019; Negash et al. 2002; Olango et al. 2014). They can thus be seen as complementary, and maintenance efforts should take both systems into account.

Examinations of the folk nomenclature systems applied to enset in Kaffa show that the names are often descriptive and reflect variations of landraces in geographic origin, plant morphology, and name of clans, objects, or animals. Folk nomenclature system is an integral part of the variety management in many farming systems (Harlan 1975) and is used to highlight the amount of genetic diversity (Brush and Meng 1997; Roder et al. 1996). This is in conformity with the findings of Hernandez (1985), who pointed out that rich knowledge of the folk nomenclature system is one of the factors accounting for maize diversity in Mexico. A similar naming pattern was observed for sorghum, yam, and enset in Ethiopia (Mekbib 2007; Olango et al. 2014; Worjje, Asfaw and Mengesha 2021).

The meaning of the names of some of the identified varieties is not known. In this study, the meanings and implied word origins of about 34% of the recorded variety names in Kaffa were not explained. As pointed out by Mekbib (2007), it is difficult to know unless the people who named it or the place of origin are traced back. The original name is adopted and maintained with variety in the course of farmer-to-farmer diffusion. Similar unexplained names were reported for yam (Hildebrand 2003; Worojie, Asfaw and Mengesha 2021) and for enset (Olango et al. 2014; Shigeta 1990; Tesfaye 2008b) varieties in Ethiopia. A similar pattern was also observed in rice in Nepal (Appa Rao et al. 2002). In the Kaffa botany of enset, the identified names are of two types structurally. Uninominal structure was more prevalent in variety names, while all the sub-varieties were labeled with binomial names. Studies from Ethiopia (Haile, Tesfaye and Olango 2022; Hildebrand 2003; Tesfaye 2008b) reported a similar labeling system for varieties and sub-varieties of yam and enset. The naming structure is also comparable with that reported for yam in Oceania (Malapa et al. 2006). The existence of two distinct naming structures on Kafficho nomenclature can be taken as clear evidence of the existence of two separate folk groups at intraspecific levels.

The determination of a variety's identity and distinctiveness is made by considering a large number of folk descriptors. Major characteristics by which farmers distinguished their enset varieties were pseudo-stem color, height, and size, midrib color, kocho and ettino quality, time to maturity, and use values (ESM 1). Similar identification customs have been reported in Ari, Sheka, and Wolaita folk nomenclature of enset in Ethiopia (Haile, Tesfaye and Olango 2022; Olango et al. 2014; Shigeta 1990). The key discrepancy between sub-varieties relies on plant attributes, principally variations in pseudo-stem and midrib colors. Similar labeling customs have been reported in Sidama and Sheka folk nomenclature of enset (Haile, Tesfaye and Olango 2022; Tesfaye 2008b). Folk descriptors recognized for enset also share the descriptors reported for yam in Ethiopia (Hildebrand 2003; Tamiru, Becker and Mass 2008) and for potato in the Andes (Haan et al. 2007; Zimmerer 1996).

Kaffa farmers have a number of other systems for grouping enset landraces. Three major ways of groupings can be recognized based on a single criterion. Each of these groupings is formed by assembling several varieties and sub-varieties together; they are thus supra-variety categories, i.e., are groupings higher than the folk variety. Ensets are classified as either wild or domestic based on their cultivation contexts. Similar trends of supra-variety category identification were reported for enset and yam in Ethiopia (Haile, Tesfaye and Olango 2022; Worojie, Asfaw and Mengesha 2021). Another grouping distinguishes ensets on the basis of use, describing them as corn use, processing, or medicinal/ritual use groups. A similar study on rice in Nepal (Appa Rao et al. 2002), on enset in Ethiopia (Shigeta 1990; Tesfaye 2008b) and on common bean in Romania (Papp et al. 2014) has shown that

name of the varieties are related to the functional value of the variety.

The third grouping distinguishes ensets based on gender. On the basis of this criterion, the Kaffa recognizes two sub-specific groupings of enset, labeling them as male or female. These are symbolic and referring to the society's perception of gender and its role and/or the different qualities preferred by male and female farmers. Gender/sex can thus influence the practical decisions of local farmers in maintaining and managing diversity. Similar way of classification was reported for enset in Kaffa area (Negash and Niehof 2004). Likewise, Haile, Tesfaye and Olango (2022) and Tesfaye (2008b) reported that other ethnic groups in Ethiopia distinguish enset landraces on the basis of sex. This gender-based classification is not limited to enset. A similar scheme exists for yam in Ethiopia (Tamiru, Becker and Maass 2011; Worojie, Asfaw and Mengesha 2021) and for plant species in Mexico (Casas et al. 2016), showing that different social groups around the world classify crop plants in a similar way.

Kaffa botany of enset allows for the recognition of a folk biological category consisting of five ranks: folk generic, folk specific, supra-variety, variety, and sub-variety (Table 1). The folk botany of enset in Kaffa shares the general folk classification schemes reported for enset, and yam in Ethiopia (Haile, Tesfaye and Olango 2022; Tesfaye 2008b; Worojie, Asfaw and Mengesha 2021), for cassava in the Aguaruna (Boster 1985) and for potato in the Andes (Brush, Carney and Huamán 1981; Brush 1992; Haan et al. 2007; Quiros et al. 1990; Zimmerer 1991). Kaffa botany of enset may also correspond to biologically recognized divisions. For instance, taxa assigned to the level of folk generic correspond well to the biologically recognized distinct genus (Baker and Simmonds 1953; Cheesman 1947). Molecular study has showed that taxa assigned to the folk varietal and sub-varietal levels correspond to the biologically recognized intraspecific taxa (Negash et al. 2002). Taxa assigned to the folk species and supra-variety categories may correspond to the biologically recognized specific and sub-specific divisions, respectively.

## Conclusions

A number of conclusions can be drawn from the study.

First, Kaffa has a system of folk classification for enset that is both systematic and well-established. It has up to five levels that are arranged hierarchically, starting from the folk genus and going down to sub-variety. On the level of folk genus, farmers recognize two well-defined taxa of ensets, i.e., *Eppo* (wild) and *Uuxo* (cultivated) ensets. On the level of folk species, the bitter cultivar groups (*Epecho*) are identified from non-bitter groups (*Uuxo*). The *Uuxo* has up to 92 varieties (and 29 sub-varieties) whereas *Epecho* altogether has only 5. Kaffa botany of enset recognizes nearly 126 named, perhaps distinct units of ensets. The upkeep of this numerous intraspecific diversity is not random; instead, a regular system of folk taxonomy within the community and across Kaffa

accompanies this maintenance. The rich folk nomenclature is also a clear testimony of Kaffa farmers' heavy reliance on enset. Such a heavy reliance on a single crop can be viewed as a means to maintain landrace diversity.

Second, folk names are often descriptive and reflect variations in geographic origin, plant morphology, and names of social groups, objects, or animals. The meaning of names shows that enset is usually exchanged according to its native label. On Kafficho folk nomenclature, the identified enset names are of two types structurally, i.e., uninominal and binomial. The binomial system of sub-variety names is similar to the Linnaean classification system, where a plant is given a two-part name that represents both the genus and species. This provides additional support to the view that plant classification is not an activity confined to the domain of formal science only.

Third, Kaffa farmers manage a wide range of folk descriptors for naming, identifying, and grouping ensets. A total of 22 characters and 86 character states were used by farmers as a key to discriminate the taxa assigned to different groups. More than 68% of the characters refer to aspects of a plant's morphology and physiology. A naming and grouping system of ensets based on morphology and physiology has definite biological implications. Farmers' also grouped ensets based on functional considerations, such as the different qualities preferred by male and female farmers and their use values. These and other related customs in Kaffa can influence practical decisions made by farmers in maintaining and managing on-farm diversity.

In conclusion, the study demonstrated the value of folk taxonomy and nomenclature in assessing genetic diversity and the underlying factors that contribute to the evolution of ensets through domestication. This study has the potential to broaden our understanding of how local communities in center of crop origin perceive and maintain diversity of less known crop plants like enset. The authors, however, were apparently constrained by time and space from adequately assessing the entire Kaffa diversity. The lists of enset landraces found in Kaffa and their implied descriptions are incomplete. Additional studies that encompass wide geographic areas are of necessary to enrich the facts presented in this paper soundly.

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### Author Contributions

Both authors contributed to the study conception and design. Ethnobotanical survey, data collection, interpretation, and analysis were performed by Teshale Tamiru Geremew. The first draft of the manuscript was written by Tsegaye Babege Worjio. Both authors commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

### Availability of Data and Materials

Other supplementary materials are available upon the requests of corresponding author.

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### Supplemental Material

Supplemental material for this article is available online.

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