

Morphological characterization of domestic vs. forest-growing *Ensete ventricosum* (Welw.) Cheesman, Musaceae, in Sheko district, Bench-Maji Zone, southwest Ethiopia

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The morphological differences between domestic and forest-growing enset (*Ensete ventricosum*) have been studied in Sheko woreda (district) of Bench-Maji Zone (southwest Ethiopia). Presence of a waxy bloom on the ventral leaf blade, tendency to discolour upon cutting, basal swelling of the pseudostem, reproductive capability, and palatability were characters pointed out by Sheko enset-growers as the characteristic differences between forest-growing and domestic enset. These differences were evaluated through measurement and observation of relevant morphological characters of 247 domestic, naturalised and forest-growing individuals in seven localities. It was found that domestic, cloned enset was distinct from seed-propagated forest enset and from naturalised enset in several important ways that loosely correspond to differences identified by Sheko and Bench farmers. Many characteristic traits of forest-growing enset reappear within five generations of naturalisation. The differences documented here reflect ongoing, ever-changing selection practices on the part of the Sheko farmers, and thus may not all be characteristic of enset throughout Ethiopia.

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Introduction

Comparisons of indigenous crops and their wild progenitors have shed light on processes of plant domestication and the advent of food production in many parts of the world (De Wet *et al.* 1976; Kaplan 1981; Nabhan *et al.* 1981; Nabhan & De Wet 1984; Smith 1992). Although the Horn of Africa is one of the world's primary centres of plant domestication (Vavilov 1951; Harlan 1969, 1971; Phillipson 1993), such comparisons have only recently been attempted in Ethiopia (D'Andrea *et al.* 1998). For indigenous Ethiopian crops grown

for their underground storage organs, such as yams (*Dioscorea* spp., Dioscoreaceae) and enset (*Ensete ventricosum* (Welw.) Cheesman (1947), Musaceae), present-day comparative studies may be our sole and disappearing avenue to understand domestication processes: poor preservation of vegetative tissue makes demonstration of domestication through archaeological data an unlikely prospect, and forested habitats that harbour uncultivated relatives as analogs to wild progenitors are endangered. In this study, I characterise morphological differences between domestic and forest-growing

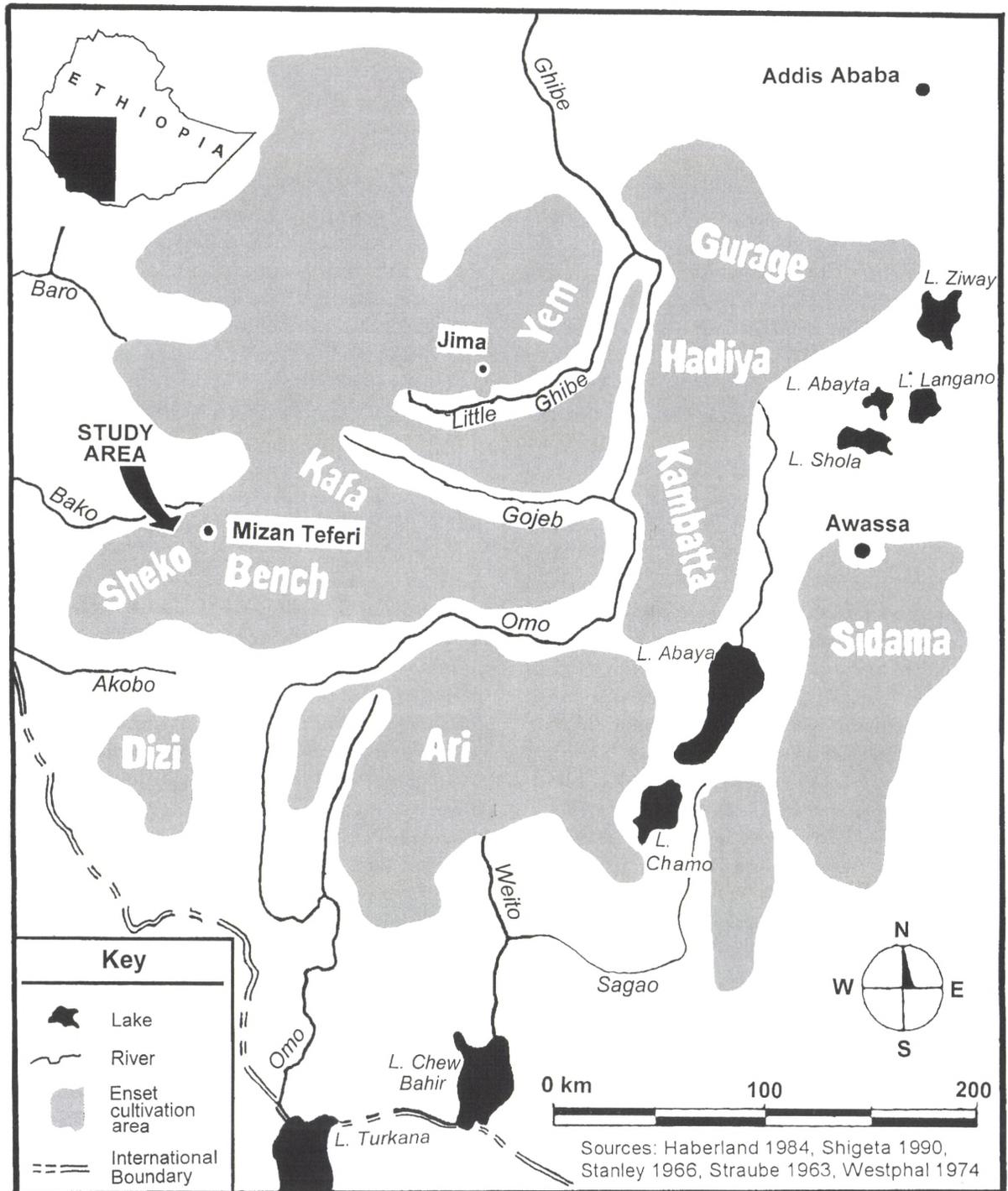


Fig. 1. Geographic regions of enset cultivation in southern Ethiopia, and major enset-cultivating ethnic groups.

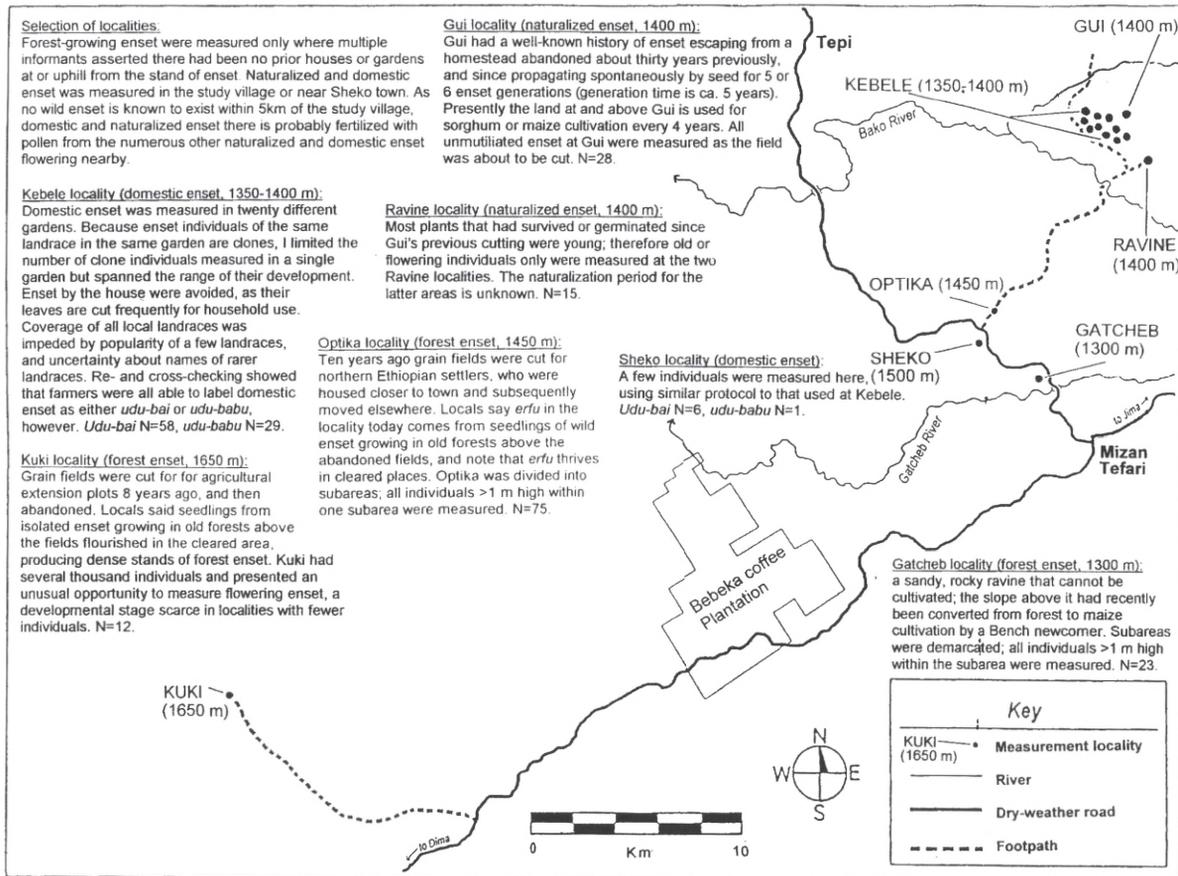


Fig. 2. Map of Sheko Woreda (District) showing enset measurement localities.

enset. (Of the many vernacular names for *E. ventricosum*, the Amharic word *enset* is used here because it is recognised throughout Ethiopia.)

Distributed across tropical and southern Africa, *E. ventricosum* is the only member of its paleotropical genus of about seven species (Lock 1993) to be domesticated and to constitute a staple food. Interactions between humans and enset span nearly the entire continuum of intensity modelled by Harris (1989), from wild procurement to full domestication. *E. ventricosum* is self-propagated via seeds and used casually through much of its range (Rossel 1998), but is cultivated intensively and

dependent on humans for vegetative propagation only in southern Ethiopia (Fig. 1). As a domesticate, enset is remarkable for its large size, multitude of uses, drought resistance, year-round availability, long maturation period, and the limited geographic spread of its cultivation. Although Shigeta (1990, 1991) has outlined general differences between wild and domestic enset in Gamo-Gofa, detailed, quantitative morphological studies of differences between wild and domestic enset have not been done. In the absence of such studies, attempts by archaeologists to model the origins of enset cultivation, enset domestication

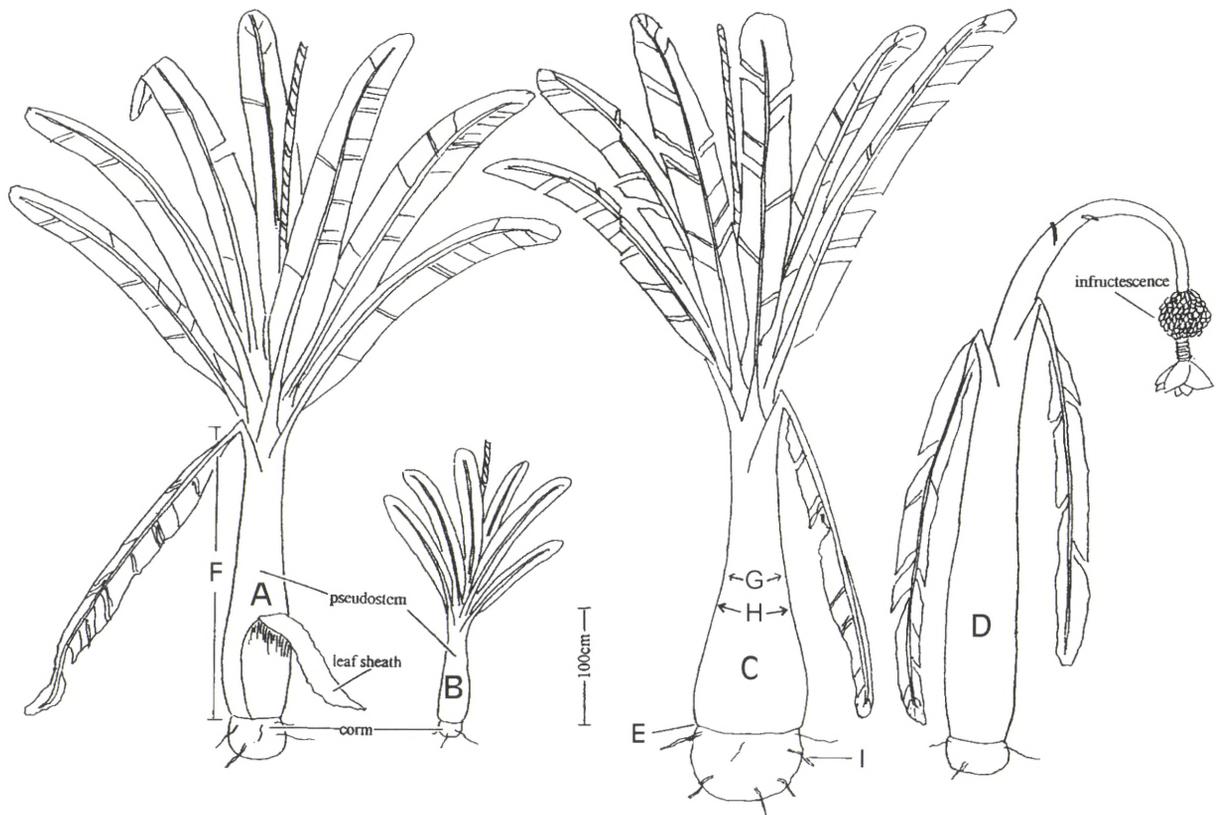


Fig. 3. Various kinds of growth stages of enset and the measurement parameters employed. **A-D:** Various kinds of growth. **A:** Full-size Sheko domestic enset c. 3 years old, non-flowering. Basal area of pseudostem almost unswollen. **B:** Young domestic enset c. 1.5 years old. **C:** Full-sized forest enset, age unknown, non-flowering. Basal area of pseudostem swollen. **D:** Enset with infructescence, c. 5 years old. The drawn individual would have a basal girth of c. 150 cm. **E-G:** Useful measurements and scaling parameters included. **E:** Basal girth measured around the pseudostem/corm junction. **F:** Height measured from the pseudostem/corm junction to the first bent-down leaf. **G:** Girth of pseudostem at halfheight measured halfway between the pseudostem/corm junction to the first bent-down leaf. **H-I:** Problematic measurements taken but not reported in this paper because they are inconsistent between individuals included: **H:** Girth of pseudostem 100 cm above the pseudostem/corm junction. This measurement could not be done on younger plants (such as B), and was still within the swollen basal area in large forest individuals (such as C). Measuring girth at an arbitrary height above the pseudostem/corm junction in a population with such a large range in height is inappropriate for scaling purposes. **I:** Root width. Some enset individuals have an entirely subterranean corm, making only upper, slender roots accessible to measurement. In other individuals, the corm protrudes above ground; deeper, robust roots are accessible but upper root wither and cannot be measured.

processes, and related social and environmental phenomena remain pure conjecture.

This study tests the hypothesis that morphological differences exist between wild and domestic enset by comparing domestic and forest-growing enset in Sheko woreda (district) of

southwest Ethiopia's Bench-Maji Zone. Sheko experts described several differences between wild and domestic enset: the presence of a wax bloom on the ventral leaf blade, tendency to discolour upon cutting, basal swelling of the pseudostem, reproductive capability, and

palatability. These were evaluated through measurement and observation of morphological characters of 247 individuals in seven localities (Fig. 2). In this paper I present primary field data supporting some of these distinctions.

Economic significance of enset

Enset is a major dietary constituent or food security resource for at least ten million southern Ethiopians (Pankhurst 1996), who grow enset for its edible corm, a squat, rounded underground stem up to 1 m in diameter (Fig. 3). The starch of corm and pseudostem of domestic enset is a palatable source of carbohydrates. Throughout much of southern Ethiopia enset is eaten as *kocho* bread: starch for *kocho* is obtained by pulverising the corm, and by ripping the fibrous exterior off of one side of each leaf sheath of the pseudostem and then scraping soft starch out of the interior of each leaf sheath. Corm and pseudostem starch is mixed, fermented in leaf-lined pits for at least a week, and baked. Scraping enset and making *kocho* were historically taboo among the Sheko, who simply steam pieces of the corm. This is common food at Sheko funerals.

Sheko do not favour steamed enset and often complain after a funeral that it has caused a bloated stomach. Nevertheless, the plant is easy to prepare quickly, available all year, and an important hedge against failure of sorghum and maize crops, which Sheko prefer but are more vulnerable to drought.

Leaf blades and petioles of cultivated and uncultivated enset are used in southwest Ethiopia for housing, clothing, bedding, cordage, wrappers, serving dishes, and many other impromptu purposes. Leaf blade and petiole use has also been observed in northern regions where enset is casually encouraged or planted but not propagated vegetatively, and local people are unaware of or choose not to make use of the food potential of the corm (Brandt *et al.* 1998). Thus, although the need for food would seem the most likely reason for domestication of enset, non-food uses also may have motivated its initial cultivation by humans.

Terms employed in this study

When one sets out to compare domestic enset in gardens, and “wild” enset growing in forest far from human settlement, one necessarily

Table 1. Categories of enset and their interactions with humans in Sheko district.

Designation	Domestic enset	Naturalised	Forest enset
Relation to humans	Cultivated	Uncultivated	Uncultivated
Sheko name	<i>Udu</i> (<i>Udu-bai</i> and <i>udu-babu</i>)	<i>Erfu</i>	<i>Erfu</i>
Sheko use	Food; fibres, building materials, coverings	Famine food; building material, coverings, fibre	Famine food; building material, coverings, fibre
Mode of propagation	Depends on humans for vegetative propagation	Self-propagates by seed; spontaneous.	Self-propagates by seed; spontaneous.
Probable ancestry	Cloned by humans for Generations	Descended from domestic enset by sexual reproduction.	Descended from wild enset via sexual reproduction.
Context	Gardens	Old gardens, abandoned gardens, village stream-banks, areas downhill from abandoned gardens	Deep forests, areas away from villages, areas with no known history of enset gardening

envisages a dichotomy between the two kinds. In fact, this strict division is blurred by self-propagating naturalised enset growing near many villages. Table 1 designates the resulting three categories of enset, and their relations to humans. To forestall confusion, the terms “domestic,” “naturalised” and “forest” will be used wherever possible in this paper. In some situations, both naturalised and forest categories are lumped together and termed “uncultivated” or “seed-propagated” enset.

The term “forest enset” is more appropriate than “wild enset” because one cannot prove that any spontaneous individual, however remote from settlements, is not distantly descended from a domestic individual. Inability to equate forest enset with a wild progenitor raises a serious question: Are differences between today’s domestic and forest enset necessarily indicative of differences between domestic enset and its wild progenitor? One cannot be sure. Opportunities to compare domestic and forest enset in proximate, environmentally similar contexts are scarce and decreasing rapidly, however; they should be taken while they still exist. The Bench-Maji zone is a good place to do so, because some old-growth forests remain, with uncultivated enset thought by locals to be truly wild, rather than recently naturalised. Moreover, as pointed out by Zemedu Asfaw (2001), there are interesting examples of domestication and naturalization in the homegardens of southwestern Ethiopia.

Deriving hypothetical differences between forest and domestic enset from indigenous observations

Shigeta’s (1990, 1991) descriptions of wild and domestic enset touch on some morphological traits; differences between the two kinds have not been evaluated, however, and formal taxonomic classification of domestic vs. wild enset

has not been done. Given the dearth of published information, indigenous knowledge and categories of enset were useful starting points in hypothesising differences between domestic and forest-growing enset. During twenty months of fieldwork in Bench-Maji zone, I had several semi-structured interviews with five adult or elder Sheko, two Bench, and one Kefa, all of whom were especially knowledgeable about enset. Interviews were repeated with most experts after several weeks or months, and the information was cross-checked with neighbours and family members.

Sheko and Bench farmers recognise two gross categories of enset. *Erfu* is any enset that has come from seed. It includes enset known to have germinated from seeds dropped from domestic enset in gardens, stands of enset in long-abandoned homesteads or the ravines below them, and enset growing deep in the forest with no known history of human interference. Sheko subcategories of *erfu* refer to midrib colour (red or white) rather than to habitat or history. Opposed to *erfu* is *udu*, the Sheko name for all cultivated enset grown from shoots produced by notching the basal pseudostem, digging out the central pith, and smearing the crevices with soil. Differences between *erfu* and *udu* as perceived by Sheko experts are presented in Table 2.

Sheko farmers subdivide domestic enset (*udu*) into two general categories, woman-enset (*udu-bai*) and man-enset (*udu-babu*), which they identify with near-universal certainty and agreement. These categories pertain to the issue of enset domestication and forest/domestic comparisons in that *udu-babu* is said to have been domesticated quite recently for use of its leaves, whereas *udu-bai* has been cultivated since ancient times for food and general use. Although Sheko recount little oral history about the origin of enset cultivation, Bench elders say that both *udu-bai* and *udu-babu* were originally *erfu* that was brought from

Table 2. Differences between forest and cultivated enset as characterised by Sheko farmers.

Trait	Domestic enset (<i>udu</i>)	Uncultivated enset (<i>erfu</i>)
White, dusty coating (“wax bloom”) on ventral leaf blade and midrib, and upper pseudostem	Present	Absent
Darkening of liquid and tissue in pseudostem shortly after cutting	Absent	Present
Adventitious roots emanating from corm	Thin	Thick
Pseudostem basal width (compared to width of upper pseudostem)	Base is same width as upper parts	Base is fat or swollen compared to upper parts
Number of seedlings under fruiting parent	None or few	Many
Colour and palatability of corm after cooking	White, soft, tasty	Black, hard, bad

the forests and planted in gardens. *Udu-bai* was domesticated in the distant past, whereas *udu-babu* was brought from forest to garden much more recently (but not within memory) to spare *udu-bai* from constant leaf-cutting. Today, the two categories have disparate uses, preparation methods, size, and timing to maturity.

Udu-bai is cultivated primarily for its edible corm, which is sweet and tender and is prepared simply by cutting into small chunks and steaming in a pot for 1.5 hours. *Udu-babu* is cultivated primarily for its leaves, which are used for many household tasks. *Udu-bai* is said to be smaller and useable after two years, flowering after three; Sheko women prefer younger, pre-flowering individuals for plain steam cooking, as the corm becomes tougher after the inflorescence emerges. *Udu-babu* is known to attain a larger size, and to flower after four or five years. Until recently Sheko ate *udu-babu* only in times of scarcity or social emergency such as a sudden funeral with few kin to provide or prepare food. Compared to *udu-bai*, its steamed corm is hard, tough, and not sweet.

Today, Sheko are learning *kocho*-making from their Bench neighbours as they discard a taboo against scraping the pseudostem. Previously, *udu-babu* and flowering *udu-bai* had little perceived comestible value due to the tough-

ness of the corm. Now such plants are often called *kocho* regardless of their original land-race name, because *kocho* is usually made from hard-cormed *udu-babu*, or newly flowering *udu-bai* whose corm is beginning to shrink and toughen. In either case, fermentation, pounding, and slicing mitigate the toughness of the corm to produce a tasty bread, and a palatable food is gained from the plant before its death.

From the above ethnographic and ethnohistorical data, I have constructed the following working hypotheses: (1) that domestic and forest-growing enset may differ in the ways described by the Sheko and summarised in Table 2; (2) that non-cloned, naturalised enset may be morphologically intermediate between domestic and forest-growing enset or have some traits associated with each category; and (3) that *udu-babu* may retain some similarities to forest enset (*erfu*) due to its alleged recent domestication for non-comestible purposes.

Methods

To test these hypotheses, morphological data was collected from 247 enset plants in Sheko district, where domestic, naturalised, and forest enset all grow in similar altitude and rainfall

conditions. Domestic enset is well-known to vary according to altitude and/or associated factors in its growth speed and ability to send forth vegetative shoots (K. Zippel, pers. comm.), and in adult size and age of flowering individuals. In a single location, domestic landraces may differ in colour of midrib, leaf axis, and sheath, as well as in size and uses; forest enset also varies in colour and dimensional attributes in a single locale. To avoid confusing environmentally-caused or intra-category variation for genuine differences between domestic, naturalised, and forest enset, research design called for large sample sizes in a geographically circumscribed area of roughly consistent altitude and rainfall, and sampling of as many domestic landraces as possible. Enset was measured at seven localities in five kebeles or townships (Fig. 2), which were all 1350-1650 m a.s.l., and all received roughly comparable rainfall.

Morphological study of enset can be difficult because of its large size (pseudostems reach 5 m in height), the ill-defined boundary between pseudostem leaf sheaths and free petioles, retention of dead tissue on the plant's exterior, and its tendency to grow in wet ravines and garden areas of rubbish, manure, and night soil accumulation. Baker & Simmonds (1953), Cheesman (1947), Simmonds (1960), and IPGRI (1996) delineate few measurement conventions pertaining to traits noted by the Sheko. Study methods were therefore devised during fieldwork and are briefly summarised below and in Fig. 3.

The white coating (wax bloom) on the ventral leaf axis was evaluated visually: it was either heavy, sparse, or absent. Discoloration of pseudostem tissue was tested by cutting off a still-living leaf sheath c. 1 m above the ground and checking its colour after five minutes and again after half an hour. A range of leaf axis tissue darkening to grey, purple, or brown was recorded, but is reported here simply as none,

light, and dark. Also observed during data collection, but not described by the Sheko, was a rapid darkening of the watery liquid in the pseudostem to a bright orange, noted during data collection on a presence/absence basis. Root width measurements proved inconclusive due to inconsistent measurement parameters: some enset individuals have an entirely subterranean corm, leaving only the uppermost, slender roots accessible to measurement. In other individuals, the corm protrudes above the soil surface, rendering the deeper, most robust roots accessible to measurement; upper roots wither and cannot be measured.

Evaluating the nature and degree of basal pseudostem swelling required choosing a location to measure the base, and appropriate scaling variables. These are illustrated and explained in Fig. 3. Sheko descriptions referred to the widest portion of the pseudostem. This location was impossible to measure consistently because of numerous dead leaf sheaths clinging to pseudostems, sometimes swollen and dripping, sometimes thin, dry, and brittle. The circumference of the pseudostem-corm junction (c. 40 cm below the widest point) was chosen because it was easy to define, clean, and measure consistently.

Fertility was evaluated by dissections of infructescences from one forest, one escaped, and two domestic individuals, and by observing infructescence and seedling development. Infructescences were obtained for dissection as the fruit began to turn orange, so that seeds were fairly mature but monkeys had not yet taken fruit away, as is common among uncultivated enset. Colour and palatability of the corm were tested during two cooking experiments performed in October 1998 and July 1999. During each experiment, forest enset from Optika locality and domestic enset from the nearest village were steamed simultaneously for 1.75 hours.

Results

Wax bloom

The Sheko characterisation of forest enset as lacking in the white dusty coating (wax bloom) on the ventral lamina and midrib is accurate (Table 3). Enset naturalised over a 30-year period (5 or 6 generations of spontaneous seed propagation after probable fertilisation with pollen of nearby domestic and naturalised enset) resembles forest enset in this regard: of 42 individuals, only four have wax blooms, which are much less marked than those on domestic enset. All domestic individuals have a wax bloom of some sort except an old, withering individual that was difficult to evaluate. Among domestic enset, the frequency of weak

wax blooms is greater among *udu-babu*; most *udu-bai* plants have obvious wax blooms.

Discoloration of tissue after cutting

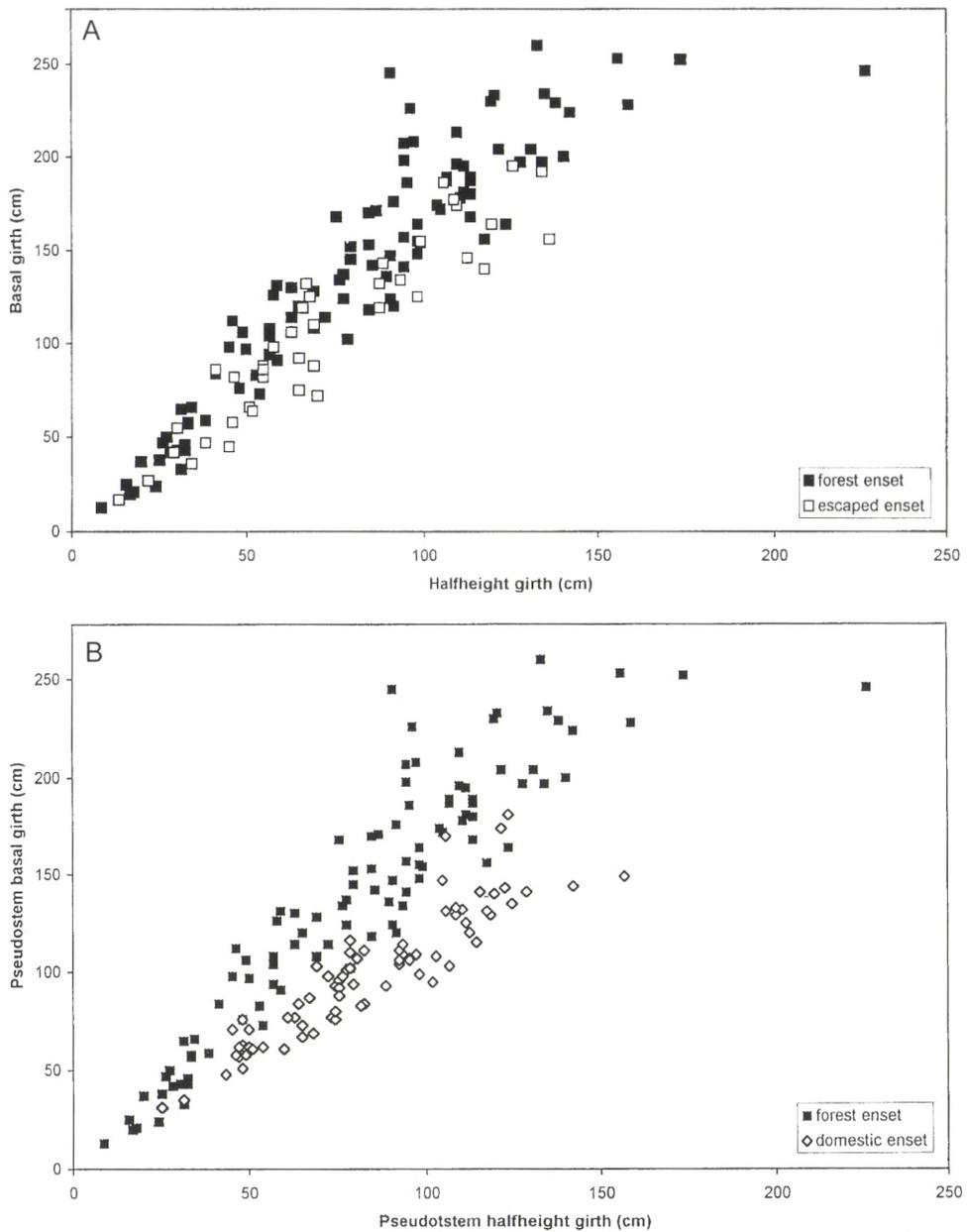
Tissue discoloration data do not bear out a dichotomous characterisation of domestic enset as white and seed-propagated enset as dark (Table 4). Although forest enset has universal discoloration after cutting, several domestic landraces also show significant tissue darkening. Heavy discoloration is uncommon among even these landraces, however. Enset escaped from cultivation 30 years before shows universal discoloration. Among both forest and escaped enset, the final colour and speed of discoloration varies.

Table 3. Presence/absence of white coating (wax bloom) on ventral leaf blade and leaf axis. Note that the wax bloom trait was not evaluated for a few individuals at the beginning of the study, and for some individuals that were old or withering, because it would have been difficult to see on dead tissue.

Enset category (local name)	Heavy wax bloom	Slight wax bloom	No visible wax bloom	No. of plants evaluated
Forest (<i>erfu</i>)	0 (0%)	0 (0%)	83 (100%)	83
Escaped (<i>erfu</i>)	0 (0%)	4 (10%)	38 (90%)	42
Domestic total (<i>udu</i>)	70 (85%)	11 (13%)	1 (1%)	82
Domestic (<i>udu-babu</i>)	21 (72%)	7 (24%)	1 (4%)	29
Domestic (<i>udu-bai</i>)	49 (92%)	4 (8%)	0 (0%)	53

Table 4. Discoloration of pseudostem tissue and liquid after cutting. Not all individuals were evaluated for this trait because cutting enset to check discoloration initially seemed potentially intrusive enough to jeopardise permission to conduct the measurements, especially among domestic enset and one stand of naturalised enset. Later, as people became accustomed to the procedures, leaf sheath cutting was integrated into the study.

Enset category (local name)	Tissue discoloration 30 min. after cutting			No. of plants evaluated	Liquid orange 5 min after cutting
	Heavy	Slight	Absent		
Forest (<i>erfu</i>)	74 (90%)	8 (10%)	0 (0%)	82	58 (71%)
Escaped (<i>erfu</i>)	31 (82%)	7 (18%)	0 (0%)	38	11 (29%)
Domestic total (<i>udu</i>)	11 (16%)	25 (36%)	33 (48%)	69	13 (19%)
Domestic (<i>udu-babu</i>)	4 (15%)	9 (33%)	14 (52%)	27	7 (26%)
Domestic (<i>udu-bai</i>)	7 (17%)	16 (38%)	19 (45%)	42	6 (14%)



Regression equations:

Significance:

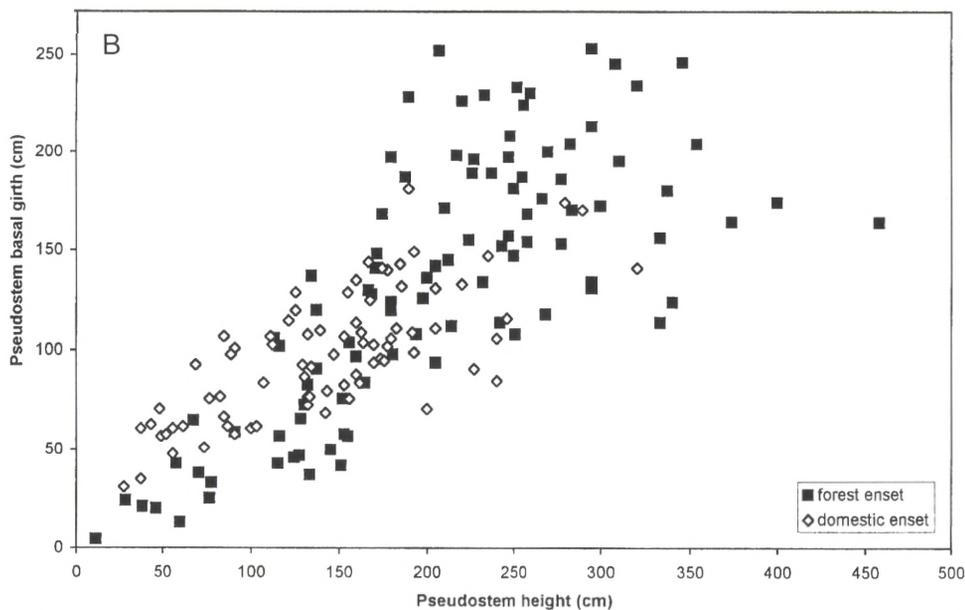
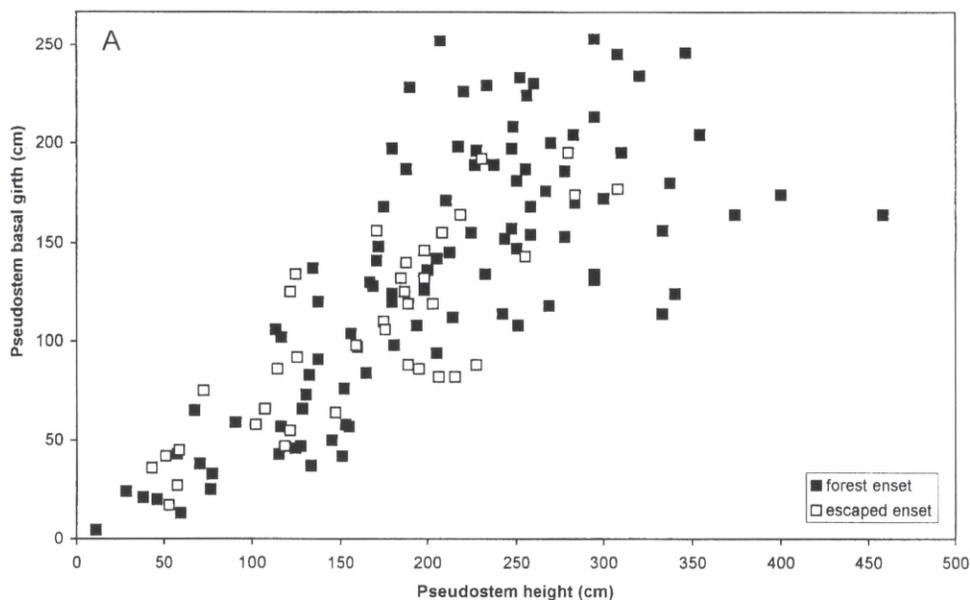
Figure 4a. Mean basal girth controlling for halfheight girth: $X_{FOREST} - X_{NATURALIZED} = 18.3$
 $Y = 17.6 + 1.5HALFHEIGHT - 12.4FOR.NAT - 0.008FOR.NATXHALFHEIGHT$

Yes; $p < 0.01$
 No

Figure 4b. Mean basal girth controlling for halfheight girth: $X_{FOREST} - X_{DOMESTIC} = 40.6$
 $Y = 17.6 + 1.5HALFHEIGHT - 7.0FOR.NAT + 0.4FOR.DOMXHALFHEIGHT$

Yes; $p < 0.01$
 Yes; $p < 0.01$

Fig. 4. Two scatter plots showing basal girth of pseudostem (vertical axis) and halfheight girth of pseudostem (horizontal axis) in a number of individuals of: **above:** forest enset and escaped enset. **below:** forest enset and domestic enset.

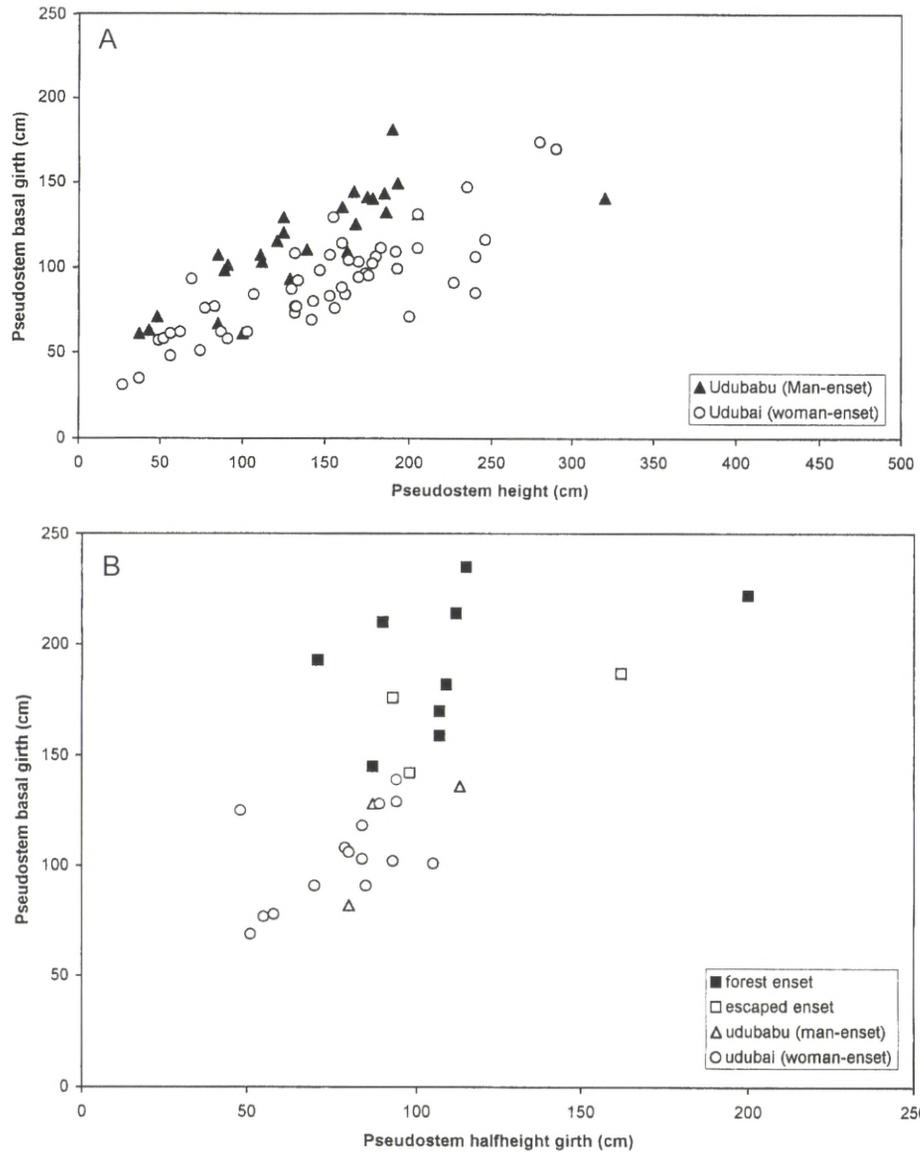


Regression equations: Significance

Figure 5a. Mean basal girth controlling for height: $X_{FOREST} - X_{NATURALIZED} = 6.34$ No
 $Y = 10.87 + 0.55HEIGHT + 9.44FOR.NAT + 0.02FOR.NAT \times HEIGHT$ No

Figure 5b. Mean basal girth controlling for height: $X_{FOREST} - X_{DOMESTIC} = 4.85$ No
 $Y = 44.64 + 0.37HEIGHT - 24.16FOR.DOM + 0.18FOR.DOM \times HEIGHT$ Yes; $p < 0.05$

Fig. 5. Two scatter plots showing basal girth of pseudostem (vertical axis) and height of pseudostem (horizontal axis) in a number of individuals of: **above:** forest onset and escaped onset. **below:** forest onset and domestic onset.



Regression equations: Significance

Figure 6a. Mean basal girth controlling for height: $X_{UDUBABU} - X_{UDUBAI} = 27.66$ Yes
 $Y = 58.62 + 0.40HEIGHT - 24.70BABU.BAI + 0.02BABU.BAI \times HEIGHT$ No

Not illustrated: Mean basal girth controlling for halfheight girth: $X_{UDUBABU} - X_{UDUBAI} = 2.3$ No
 $Y = 18.4 + 1.0HALFHEIGHT + 15.1BABU.BAI + 0.2BABU.BAI \times HALFHEIGHT$ No

Fig. 6. Two scatter plots showing: **above:** basal girth of pseudostem (vertical axis) and height of pseudostem (horizontal axis) in a number of individuals of man-enset and woman-enset. **below:** basal girth of pseudostem (vertical axis) and halfheight girth of pseudostem (horizontal axis) in a number of individuals of flowering enset.

Dimensional differences in the pseudostem base

Dimensional measurements generate an ontogenetic picture of basal pseudostem girth in comparison to halfheight girth (Fig. 4a, 4b, 6b) and height (Fig. 5a, 5b, 6a); differences in the regression slopes can also indicate differences in the rates of expansion in the pseudostem base *vs.* other scaling factors. Forest enset's basal and halfheight girths correlate well throughout its development. Naturalised enset's basal girths are significantly less than those of forest enset, but the two regression slopes do not differ significantly (Fig. 4a). Domestic enset (*udu*) has a consistently smaller basal/midheight girth ratio and shallower regression slope than does seed-propagating enset (Fig. 4b). Basal/halfheight circumference scaling corroborates the Sheko characterisation of forest enset (*erfu*) as basally swollen compared to domestic enset, and suggests that basal girth of domestic enset increases more slowly throughout development than that of forest enset.

Scaling pseudostem basal circumference against pseudostem height reveals a more complicated situation. Forest enset's basal girth/height ratio varies greatly throughout its development. The girth/height ratio for naturalised enset has a similar range and distribution and follows a similar regression slope (Fig. 5a): domestic enset has a larger base/height ratio than seed-propagated enset early in its development, but after attaining a maximum basal circumference of c. 140 cm, domestic enset grows only vertically, whereas forest enset continues gaining in both height and girth (Fig. 5b).

At all stages, *udu-babu* has a greater basal girth/height ratio than that of *udu-bai* and a steeper regression slope as well (Fig. 6a); no significant difference is found in either the basal girth/halfheight girth ratio or the regression slope of *udu-bai* *vs.* *udu-babu*, however (not illustrated; regression equation follows Fig. 6a

and its equation). Flowering individuals show a clear disjunction between the maximum dimensions attained by domestic *vs.* seed-propagated enset: basal girths of domestic flowering individuals are less than 140 cm (mean=106, n=18) while those of forest enset all exceed 142 cm (mean=186, n=12) (Fig. 6b).

Fertility: seed development in forest and domestic enset infructescences

Dissection and observation both verify Sheko assertions that forest enset is extremely prolific but domestic enset is not, even when allowed to flower. Dissection of infructescences from two domestic, one escaped, and one forest enset shows a marked difference in the number of well-formed, seemingly viable seeds per fruit, and per infructescence (Figs. 7, 8). Infructescences of forest and naturalised enset have thousands of seeds, while domestic enset infructescences have few fruits with full-sized seeds, and low numbers of seemingly viable seeds in each such fruit. Forest enset infructescences have plump fruits like squat bananas; hundreds of heavy, hard, black seeds c. 12 mm in diameter drop from a single individual, germinate, and seem hindered in their growth only by excessive crowding. The thumb-sized fruits of domestic enset bear mostly seeds c. 3 mm in diameter that are obviously incompletely developed. Some domestic fruits contain seeds that are full-sized (c. 12 mm) but pale and soft. Black, hard, full-sized seeds indistinguishable from those of forest enset are present but infrequent in domestic infructescences.

Dissection-based assessments of potential seed viability should be ideally tested by experiments, but are supported by observations of forest and garden enset seeds throughout the study. Although garden enset seeds fall into disturbed, rich soil with plenty of sunlight and moisture, on most occasions few or none from *udu* germinate. No seedlings developed from

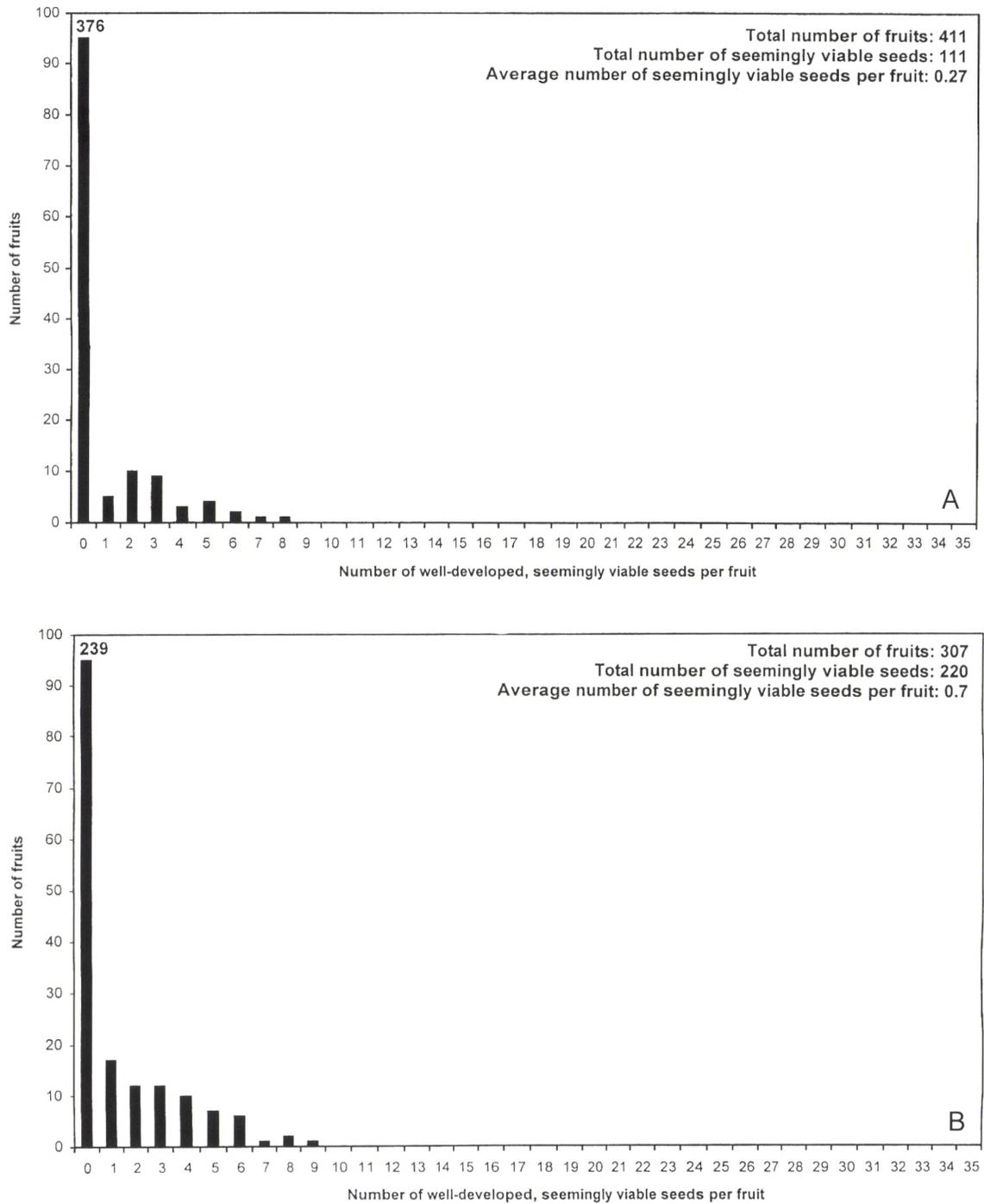


Fig. 7. Two bar charts showing the number of well-developed and seemingly viable seeds per fruit in two different infructescences of domestic enset from the Kebele locality. **above:** Infructescence 1. **below:** Infructescence 2.

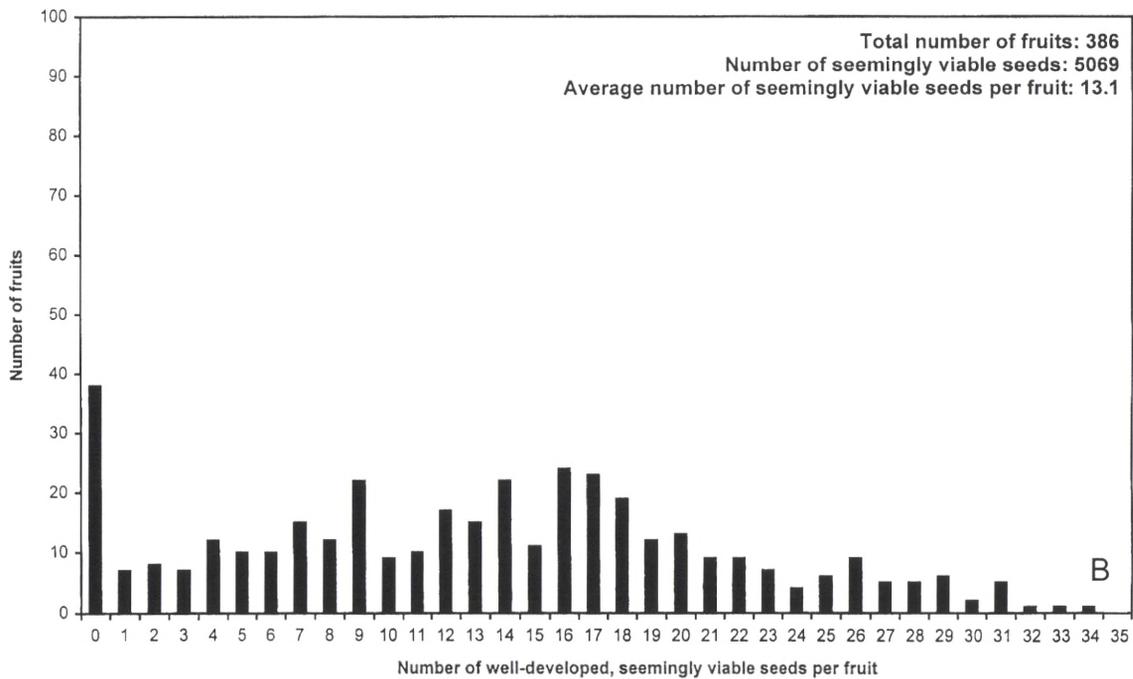
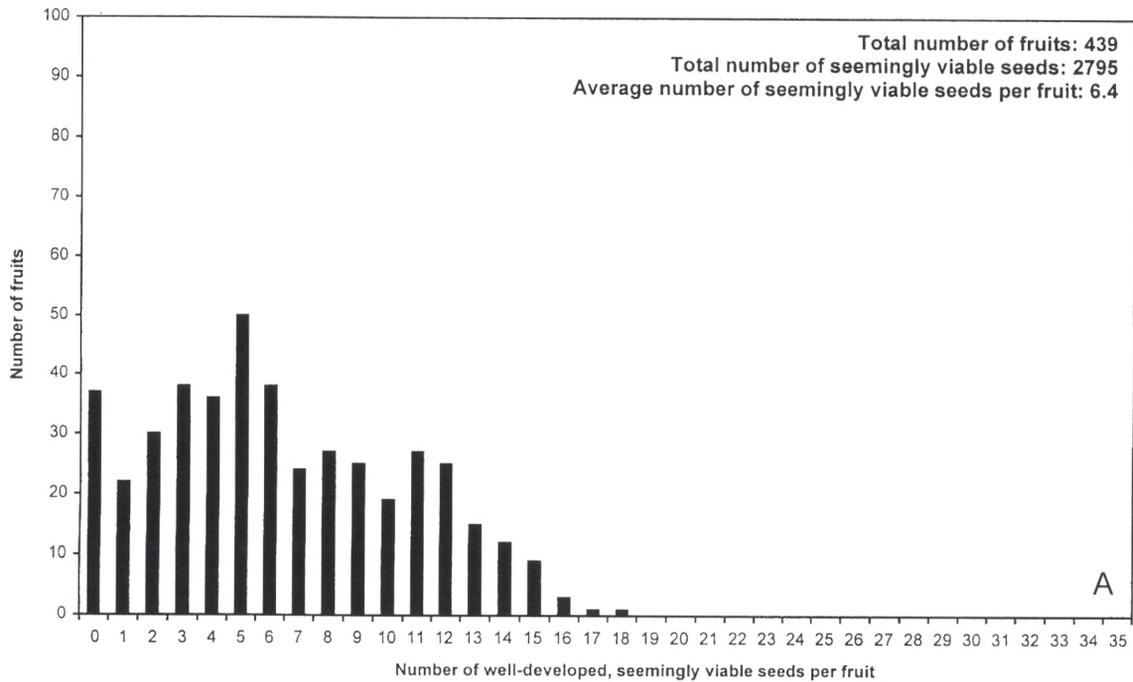


Fig. 8. Two bar charts showing the number of well-developed and seemingly viable seeds per fruit in infructescences of naturalised enset and forest enset. **above:** naturalised enset from Gui locality. **below:** forest enset from Optika locality.

eight domestic infructescences flowering in separate gardens and ten individuals in a single garden without human interference. One domestic infructescence yielded three small seedlings that grew for a month but then disappeared. In another garden, however, one seedling had grown to adulthood and was referred to as *erfu*. It bore an infructescence that resembled those of forest enset: at the time of discovery half of the fruits had fallen and 355 seedlings had germinated in a 30 x 30 cm area beneath the drooping infructescence; remaining fruits were fat and each contained 14-17 seeds. The first-generation *erfu* and the dissected naturalised infructescence show that sexual reproduction quickly restores fertility.

Palatability of the enset corm: oral history and cooking experiments

The first cooking experiment at Optika corroborated claims by northeastern Sheko that *erfu* is not palatable. Corm chunks from a large *erfu* steamed for 2 hours failed to attain the white, fluffy, soft, starchy consistency (similar to a well-baked potato) of *udu* steamed for the same period on a similar fire. *Erfu* stayed hard, grey, solid, and tough; when squeezed, the hot corm chunk dripped water. Extending the steaming overnight achieved only a more rubbery consistency. *Erfu* consumption did not cause any unusual digestive disturbances, however. The first experiment suggested that *erfu*, while probably not poisonous, was certainly a tough, undesirable food source.

Subsequently, southwestern Sheko elders reluctantly recalled a period when inter-tribal hostilities had forced them to flee their farms. They lived in the forests for a year, and ate *erfu* after other resources ran out. Elders advised me that smaller individuals, with pseudostems about 2 m tall, were better than large ones. A second set of cooking experiments at Optika bore out these statements: steamed corm from a 2 m tall *erfu* attained a starchy consistency no

worse than domestic *udu-babu* served during an exceptionally sudden and difficult funeral two weeks previously. Optika Sheko, though still unenthusiastic about eating it, were surprised by its cooked appearance and said it was "like *udu-babu*." The two cooking experiments show that full-grown *erfu* with a large corm is unpalatable, but younger *erfu* with a smaller corm is tender and quite edible.

Discussion

Although field data appear to substantiate many Sheko folk distinctions between forest and garden enset, their pertinence to deliberate or inadvertent selection on the part of farmers remains unexplored. A few preliminary ideas are offered here.

Wax bloom

The white coating on the abaxial leaf blade, midrib, axis, and upper sheath is a wax bloom. A wax bloom occurs only if the length or width of a plant's epicuticular wax projections approximates the wavelength of light; the projections scatter the light and produce the visual effect of the wax bloom, which exists on a wide range of plant taxa including leaves of *Eucalyptus* sp. and *Brassica* sp., and the fruits of plums (*Prunus domestica*) (Martin & Juniper 1970). Rubbing the surface disturbs the configuration of wax projections and eliminates the scattering effect. As well as on cultivated enset, wax blooms appear on abaxial leaf surfaces of its close relatives *Heliconia* sp. and cultivated *Musa* (Personal observations during fieldwork (*Musa* sp.) and at the Missouri Botanical Gardens' Climatron (*Heliconia* sp.)). Systematic SEM studies of epicuticular wax ultrastructure have shown that *Ensete ventricosum*, *Musa* spp., and *Heliconia* spp. all have the "Strelitzia-type" of epicuticular wax, consisting of compound rodlets, shared by many farinaceous monocots (Fröhlich & Barthlott 1988). Those listed by Fröhlich &

Barthlott (1988: 106-107) are *Musa acuminata*, *M. rosacea*, and *M. sapientum*; *Heliconia aurantiaca*, *H. marginata*, *H. collinsiana*, *H. mariae*, *H. wagneria*, and *H. swartziana*. The enset specimen is listed as *Ensete ventricosum*; the authors do not state whether it is wild or cultivated, nor name its country of origin.

The lack of a wax bloom on forest and most naturalised enset does not signify a lack of epicuticular wax, however. Rather, it indicates that light scattering is minimised because dimensions of wax bodies on uncultivated enset differ from the wavelength of light. This could be due to a slight dimensional disparity, or to gross differences in wax body configuration or composition, as the ultrastructure of wax bodies is often linked to their chemical constituents (Jeffree 1986; Jeffree *et al.* 1976). Documenting a tendency for many “*Strelitzia*-type” waxes to be made up mainly of wax esters, Meusel *et al.* (1994) note that although *Musa paradisica* follows this trend, wax of *M. acuminata* and *M. balbisiana* consist less of wax esters than hydrocarbons, primary alcohols and fatty acids. The consequences of these compositional differences for configuration of *M. acuminata* and *M. balbisiana* waxes are not yet certain, but it is clear that wax constituents and, presumably, configuration can vary considerably even within a genus. Understanding variation in wax ultrastructure between domestic and uncultivated *Ensete ventricosum* will require examination of wax configuration via SEM, and molecular characterisation of wax constituents.

Pending such research, the possible functional significance of epicuticular wax ultrastructure deserves mention. Certain configurations of wax bodies can inhibit gas exchange, reducing water loss via transpiration in hot or dry environments (Martin & Juniper 1970). Epicuticular wax can serve many other functions, however (Baker 1982, Riederer & Markstadler 1996). In this study, observations of

heavy wax blooms on domestic enset in hot, sunny gardens compared with bloomless forest enset in cooler, shady habitats would suggest that the domestic-type wax configurations might be more effective in limiting water loss. Bloomless naturalised enset growing in hot, uncanopied abandoned gardens and sunny streambanks are inconsistent with the above trend, however: sexual reproduction appears to restore forest-type (bloomless) wax in naturalised enset, despite hot conditions in which limits on transpiration would be advantageous. This raises questions as to 1) how naturalised enset reverts to forest-type traits in so few generations of sexual reproduction (discussed later), and 2) whether bloom-producing domestic-type wax configurations have any functional significance. The latter question should be evaluated in future studies documenting rates of water loss in enset plants with each kind of wax.

Discoloration of enset tissue after cutting

Distinctions in tissue discoloration between domestic and forest enset, although not so consistent as Sheko farmers suggest, might indicate the presence of polyphenols in pseudostem tissue (J.M. Lock, pers. comm.). Tannins have been found previously in *Musa* leaves (Gibbs 1974; Tomlinson 1969). Tomlinson (1959) also reports tannins in undifferentiated *Musa* tissue and describes “articulate laticifers associated with the vascular bundles of all organs except the root, the mucilaginous contents of these elements exuding at cut surfaces and darkening on exposure to air” (p. 794). Polyphenols in *Musa* spp. and uncultivated enset probably discourage their consumption by insects and other animals (D. Milanowski, pers. comm.). They did not deter elephants formerly present in the region from eating forest enset, however.

Sheko lumped dark colour and bad taste as universal traits of forest enset. One might con-

clude that polyphenols have been selected against during or after domestication due to their harsh flavour. The domestic landrace *arka*, however, had prompt, obvious tissue discoloration, and was popular both in terms of the number of gardens it appeared in and in terms of the number of individuals per garden. *Arka*'s tissue discoloration did not signal poor taste to Sheko farmers. It may be that the polyphenols causing discoloration of the degree observed in *arka* are sufficiently diminished in intensity as to not affect comestibility. Testing for tannins among corms of all domestic landraces, and quantitative comparisons of tannin concentrations between various landraces and forest enset would be useful starting points for biochemical study of the differences between domestic and forest enset.

Sheko did not seem to be aware that orange discoloration of pseudostem liquid was a common trait among forest enset. One domestic landrace was named *yerbm-udu* ("blood-enset") for its tendency to "bleed" orange or pink liquid if the pseudostem was cut. On one occasion that Sheko witnessed an *erfu* "bleeding," they said it was "like *yerbm-udu*," rather than the converse: they related the forest individual to the one domestic landrace that bleeds, rather than recognising that the *yerbm-udu* landrace has a trait that is widespread in *erfu*. The exact nature of compounds causing both kinds of discoloration will require biochemical investigation.

Dimensional differences in the pseudostem base, and motivations for selection

Pseudostem basal girth/height ratios do not differ significantly between *udu* and *erfu*, which may reflect the great variation in basal girth/height among forest enset. Their regression slopes do differ significantly, however: domestic enset tends to attain a large base earlier in development, and its base increases more slowly later, as the plant gains height

(Fig. 5b). Growth of forest enset's basal area appears to be steadier throughout its development. Domestic enset flowers and dies while the plant is smaller in all respects, whereas forest enset attains much greater overall size before flowering (Fig. 5b, 6b). Forest and domestic enset have quite disparate basal girths at the time of flowering, regardless of height (Fig. 6b). Domestic enset's basal girth is significantly smaller, and grows significantly slower than that of forest enset using halfheight girth as a size control (Fig. 4b). The basal/midheight girth ratios for domestic enset lie mostly outside the range of variation for forest enset, indicating that even after bringing enset individuals from forest to domestic contexts, humans have continued to select (consciously or unconsciously) for a smaller basal area among their cultivated enset.

Cooking experiments have provided one possible impetus for selective reduction in basal girth: a narrower base corresponds to a smaller corm that is more likely to be tender and palatable. They also suggest that selection has been done in the absence of *kocho* technology, which renders large, tough enset more palatable and lessens incentives to select for narrower bases or smaller corms. But the cooking experiments have raised another question: if immature forest enset can yield tender individuals, why initiate cultivation? There are three possibilities: first, enset may have reproduced poorly in a heavily forested preagricultural landscape and not been sufficiently abundant, so that people may have viewed intervention as necessary simply to sustain it. Second, people may have sought to expand the distribution of enset beyond its natural range to more convenient locations in their seasonal round. In either of these cases, selection of narrower-based, more palatable individuals for propagation may have been deliberate or incidental. Third, people may have had plenty of enset but

consciously sought to enhance palatability through deliberate selection.

Comparisons between *udu-bai* and *udu-babu* are interesting in view of their different histories and uses. Pseudostem bases (scaled against height) are significantly wider in *udu-babu*, which also has a significantly steeper regression slope than *udu-bai* (Fig. 6a). Tissue discoloration was similar between the two, and obvious wax blooms are slightly less prevalent among *udu-babu*. The fact that one scaling factor (height) produces significant differences between the two kinds but the other (halfheight) does not makes interpretation difficult, however. It is possible that *udu-babu*'s corm size has not been reduced as much as that of *udu-bai* due to a shorter period of human selection, or to palatability concerns being less important due to its use for leaves or *kocho*. *Udu-babu*'s other traits may have been subjected to similar selective forces as those of *udu-bai* or responded to these forces more quickly. Such conclusions are premature considering the limited number of individuals and landraces sampled, however; additional measurements and interviews are called for.

Naturalisation of garden enset

In comparison to forest enset, naturalised enset has significantly smaller basal/halfheight girth ratios (Fig. 4a) but similar regression slope for growth of basal girth (Fig. 4a, 5a). Naturalised enset's observed range of viable seeds per fruit (0-18) falls short of that reported by Baker & Simmonds (1953) for wild *E. ventricosum* throughout East Africa (0-35), with which this study's dissections of forest enset (0-34 seeds per fruit) concur. Such differences tend to support the premises that forest enset, even if naturalised in the distant past, has at least regained full fertility relative to that of truly wild enset, and that forest and naturalised enset in Bench-Maji zone are indeed distinct from one another.

On the other hand, naturalised enset's reversion to forest forms of several traits (partial restoration of fertility, increased tissue discoloration, and loss of epicuticular wax bloom), within five or six generations and in a habitat similar to a domestic garden, is also interesting. One possible explanation for this would be hybridisation between naturalised enset and forest enset, whereby genetic material from the latter would cause the reappearance of forest-enset traits. The difficulty with this explanation is that forest enset is rare around the study village (Kebele locality) and naturalised enset localities (Ravine and Gui). When I sought *erfu* near the study village, farmers said elephants had eaten all of the local forest enset in times past, and could only direct me to "*erfu*" in or below extant or abandoned gardens, which was probably naturalised. During 18 months of residence and frequent foot trips through the forest to several nearby settlements and market towns, Optika locality proved to be the nearest known substantial, longstanding population of forest enset to the study village. Because Optika lies 8 km and over a 1700 m ridge from the Gui and Ravine localities (Fig. 2), a more likely pollen source for enset in the study village would be other local domestic or naturalised enset. At least twenty domestic and ten naturalised enset were flowering in the study village during 1998-1999, all less than 2 km from the Gui and Ravine localities.

How could sexual reproduction between domestic and/or naturalised enset individuals result in the observed reversion to so-called forest enset traits? Each domestic landrace has been cloned for countless generations and may also have been highly inbred in the past; any hybridisation between different landraces, or between domestic and naturalised enset, might generate offspring of F1 hybrid genotype with increased fertility, that phenotypically resemble other non-inbred, sexually reproducing forest enset. If this is indeed true, landraces

can best be maintained via somatic reproduction and the Sheko differentiation between *udu* (shoot-propagated) and *erfu* (seed-propagated) is in fact the most salient distinction among the enset of Bench-Maji Zone.

Differences between forest and domestic enset in other regions of Ethiopia

Observations by fieldworkers in other zones of Ethiopia are at odds with at least one of the distinctions documented in this study (Shigeta 1991; Fekete Woldeyas 2000; Zemedede Asfaw pers. comm.). Although most of these reports are not yet published and do not rely on quantitative morphological data such as that gathered in this study, they indicate that in areas of Ari (Gamo-Gofa Zone) and Kefa (Kefa-Sheka Zone), domestic enset actually has a fatter pseudostem base than spontaneous enset growing in nearby forests (Table 5). In all of these areas, *kocho*-making or other methods of enset processing are done routinely, mitigating large-based enset's palatability problems. Under these circumstances, farmers might deliberately select for large-based enset because of its higher yield. The preference and selection for

small-based enset documented in this study may be unique to the Sheko and other peoples who do not scrape or ferment enset.

Shigeta's research also reveals that Ari define "wild" and "domestic" enset in a different way than Sheko do. Ari definitions are based on spatial context and use: seed-propagated enset appearing spontaneously in gardens may be adopted by a farmer as domestic, and may be re-cloned and incorporated into the agricultural system. Sheko definitions are based on mode of propagation and much more rigid: clones are "domestic," and seedlings are "wild" and not to be eaten or re-cloned, though they may be used opportunistically for non-comestible purposes. Ari appear to have a mechanism in place for "wild" genetic material to enter the agricultural sphere via cloning of seedlings, but the Sheko do not. Ari practices of cloning seedlings blur distinctions between "wild" and "domestic" enset and could hinder strict morphological comparison. Contrasts between the Ari and Sheko systems may however, yield fascinating insights about domestication and selection processes in both prehistoric and recent times. They also indicate that for-

Table 5. Differences between wild and domestic enset in areas inhabited by the Ari, southwest Ethiopia. Most information in this table comes directly from M. Shigeta's unpublished doctoral thesis, page 129. For additional published descriptions see also Shigeta 1990, 1996; Ari enset cultivation practices clearly differ in many important respects from those of the Sheko.

Shigeta's category/Ari name	Domestic enset/ <i>Agemi</i>	Wild enset/ <i>Gela</i>
Relation to humans	Cultivated	Uncultivated
Use by Ari	Food, other multipurpose uses	Not utilised
Context	Gardens near houses, 1200-2800 m	Swamp, riverbank, ritually taboo areas, 1200-1600 m
Base of pseudostem	Enlarged	Not enlarged
Corm size, taste	Big, not bitter	Small, bitter
How Shigeta's categories of "domestic" and "wild" enset may both contain naturalised enset (from Shigeta 1991 text, passim)	Category includes enset grown from seeds and tolerated or encouraged in Ari gardens; farmers may later re-clone a seedling with traits they desire.	Category includes spontaneous enset appearing near agricultural settlements; this enset may be naturalised rather than wild.

est/domestic morphological comparisons and ethnobotanical interviews among several other enset-cultivating peoples are needed, and generalisations regarding enset domestication processes across southern Ethiopia may prove elusive.

Conclusions

Domestic, cloned enset in Sheko district is distinct from seed-propagated forest and naturalised enset in several important ways that loosely correspond to differences identified by Sheko and Bench farmers. It possesses a visible epicuticular wax bloom and has a reduced tendency to discolour upon cutting. Its base is narrower (scaled against circumference at half-height) than that of seed-propagated enset, and it flowers and dies at much smaller dimensions than forest enset. Perhaps linked to smaller size is a tendency for domestic enset's corm to be more tender and palatable. Fertility of domestic enset is severely reduced, but if sexual reproduction is allowed and generates any viable offspring, then forest traits and partially restored fertility appear within five generations. Differences in basal pseudostem girth suggest that human selection for smaller corms continued well after enset was brought into gardens, and that *udu-bai* has been subjected to longer or more extreme selection than *udu-babu*. Maintenance of sufficient enset populations, expansion of enset distribution, and increased corm palatability are among possible motives of the prehistoric hunter-gatherers who first undertook enset husbandry. Diverse enset processing practices of other ethnic groups in southern Ethiopia may have led their farmers to have different priorities in selecting for corm size *vs.* palatability, however. The differences between domestic and forest enset documented in Sheko district through interviews and morphological study cannot be generalised throughout Ethiopia; rather, they

reflect ongoing, ever-changing relations between the Sheko people, their enset cooking technology and ideology, and the traits they favour in an enset plant. Understanding such relations among a number of enset-cultivating ethnic groups may well reveal other patterns of people-enset interactions, as the domestication process continues.

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