The participatory domestication of West African indigenous fruits[1]

R.R.B. LEAKEY*, K. SCHRECKENBERG # and Z. TCHOUNDJEU ✦

* Agroforestry and Novel Crops Unit, School of Tropical Biology, James Cook University, Cairns, QLD 4878, Australia
# Overseas Development Institute, 111 Westminster Bridge Road, London SE1 7JD, England, UK
✦ World Agroforestry Centre (ICRAF), BP 2067, Yaoundé, Cameroon

Email: roger.leakey@jcu.edu.au, k.schreckenberg@odi.org.uk, z.tchoundjeu@cgiar.org

SUMMARY

This study obtained quantitative data on fruit and nut traits from two indigenous fruit trees in West Africa (*Irvingia gabonensis* and *Dacryodes edulis*), which have led to the identification of trees meeting ideotypes based on multiple morphological, quality and food property traits desirable in putative cultivars. The same data also indicates changes in population structure that provide pointers to the level of domestication already achieved by subsistence farmers. *D. edulis* represents 21–57% of all fruit trees in farmers' fields and plays an important part in the economy of rural communities. An investigation of the socio-economic and biophysical constraints to indigenous tree cultivation found that indigenous fruits could play an even greater role in the rural economy of West and Central Africa. The opportunity to build on this through further domestication of these species is considerable, especially as retailers recognise customer preferences for certain *D. edulis* fruit traits, although at present the wholesale market does not. This project was linked to a larger participatory tree domestication programme within ICRAF's[2] wider agroforestry programme with traditionally valuable indigenous trees. Together these projects provided insights into the value of domesticating indigenous fruit trees, which are of strategic importance to poverty alleviation and sustainable development worldwide.

Keywords: agroforestry, *Irvingia gabonensis*, *Dacryodes edulis*, livelihood benefits, rural development

INTRODUCTION

Throughout the tropics there are indigenous tree species that produce locally important fruits and other non-timber forest products, that have the potential to be domesticated to provide economic and livelihood benefits to subsistence farmers (Leakey and Simons 1998). Many of these species are valuable sources of nutrition (Leakey 1999) with important health benefits against malnutrition and possible nutritional benefits conferring enhanced resilience to epidemics such as AIDS/HIV (Barany *et al*. 2001). The integration of these species as novel crops within existing farming systems can also provide environmental benefits (Leakey and Tchoundjeu 2001). The need for greater emphasis on the cultivation and domestication of these overlooked 'Cinderella' species in 'development' programmes, poses important policy questions which need to be addressed (Leakey and Tomich 1999).

The purpose of this paper is to draw attention to a participatory approach to agroforestry tree domestication, which has been developed in West Africa and that may have application in other tropical areas. This is done in the knowledge that there is considerable current interest in tree domestication in Latin America (Clement and Villachica 1994, Prance 1994, Sotelo Montes and Weber 1997, Jaenicke *et al*. 2000, Weber *et al*. 2001), southern Africa (Maghembe *et al*. 1998), East Africa (Simons 1996) and South East Asia (Reshetko *et al*. 1999) and that at the Regional Preparatory Conference of Latin America and the Caribbean for the 'World Summit on Sustainable Development', in Rio de Janeiro (23–24 October 2001) there were recommendations that:

1. International cooperation should be strengthened in order to address the issues of extreme poverty, underdevelopment, unsustainable production and consumption patterns, environmental degradation and inequities in wealth distribution.
2. Programmes should be promoted for the conservation and sustainable use of biodiversity, which also ensures equitable access to the benefits afforded by the use of genetic resources.

Although domestication does not necessarily assure conservation and sustainable use of biodiversity, this study suggests that at least while there is a substantial wild resource, as in the case of most indigenous fruits, domestication can increase intra-specific diversity (Leakey *et al*. in press a). Consequently, one way to address these

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resolutions would be to initiate a programme to domesticate more indigenous fruits, which can contribute to the reduction of poverty and livelihood enhancement (Poulton and Poole 2001) and diversify farming systems (Gockowski *et al*. 2001).

Participatory domestication

In contrast to the widely cultivated agricultural and horticultural crops of the world that have been domesticated for millennia, the initiatives to domesticate some of the indigenous fruit trees of different eco-regions of the tropics (Leakey and Simons 1998) are starting now with wild, or virtually wild, gene pools. This imposes responsibilities on the scientists involved to develop an understanding of the potential of the species; to ensure that domestication proceeds wisely, efficiently and within the constraints imposed by the Convention on Biological Diversity, and to maintain and protect the diversity of the genetic resource.

Tree improvement and breeding has usually been the prerogative of national and international research institutes, because of its long-term nature and the emphasis on timber production by government forestry departments. In agroforestry, however, with the greater emphasis on the social, cultural and economic needs of resource-poor subsistence farmers, there has been a recent shift towards domesticating trees producing valuable non-timber forest products with the people and for the people (Sanchez *et al*. 1997; Tchoundjeu *et al*. 1998). This requires a very different approach to tree improvement, one based more on horticultural than forestry techniques (Leakey and Jaenicke 1995); and one situated on the farm rather than in a research station.

The model, which has been developed in Cameroon and Nigeria by ICRAF and partners (Tchoundjeu *et al*. 1998, Kengue *et al*. 2002), is based on involving the farmers in all stages of the process. This starts with asking the farmers about which of the trees from the natural forest they would like to cultivate on their farms (Franzel *et al*. 1996), and progresses to the development of simple, low-technology plant propagators (Leakey *et al*. 1990) in the villages. These inexpensive and effective propagators, made from readily available products (wood, sand and polythene) for the rooting of stem cuttings, do not require running water or electricity. This simple and appropriate technology has many benefits for rural development projects over more complex propagation systems, especially micro-propagation, as with the involvement of NGOs, villagers are trained in the basic principles of vegetative propagation so that they can themselves produce and bulk up ‘cultivars’ from the trees that they know and like best in their area. This emphasis on the empowerment of the community and its use of indigenous knowledge about superior phenotypes in the forest allows rapid progress to be made, as it overcomes the need to do expensive and time-consuming mass propagation and selection from populations of seedlings with unknown potential. This is particularly important, when there are a number of different fruit characteristics that together form a ‘plus-tree’ or ideo type (Atangana *et al*. 2002, Leakey *et al*. 2002), as the more traits for which selection is desired, the larger is the number of trees that would need to be screened in a research station approach to tree improvement.

Participatory domestication also allows farmers to be the beneficiaries and guardians of the use of their indigenous knowledge about inter- and intra-specific variation in the population, and germplasm derived from it. This approach conforms to the aims of the Convention on Biological Diversity, which seeks to protect the rights of local people to their indigenous knowledge and germplasm. It is, thus, in stark contrast to the ‘research station model’ of tree domestication. It does, however, require that the farmers are informed about, and understand, their rights and know how to maintain and protect these rights.

Are subsistence farmers interested in domestication?

To determine the relevance of agroforestry tree domestication to subsistence farmers in West and Central Africa, a socio-economic study to examine both the constraints and potential benefits of bringing indigenous trees into cultivation was carried out in Cameroon and Nigeria. The detailed results of this study will be reported elsewhere (Schreckenberg *et al.* 2002, Degrande *et al.*, in prep, Mbosso *et al.* in prep). The overall conclusions of this study, obtained through participatory community-level research, household surveys and whole-farm fruit tree inventories were that farmers in the study area are very interested in the cultivation of indigenous fruits (Mbosso 1999). Of particular importance in southern Cameroon is *Dacryodes edulis* (safou / African plum), which is widely planted and constitutes 21–57% of all fruit trees in farmers' fields (Schreckenberg *et al.* 2002).

In all four Cameroonian communities, safou is very important for home consumption. In two communities, Chopfarm and Elig Nkouma, it was ranked higher than all other tree species for its food value, and in the others it was ranked either second or third. Women particularly like the fact that the boiled or roasted fruit can be eaten with cassava providing a meal that is quick and easy to prepare at a time when most labour has to be devoted to agricultural activities.

In addition to its use for direct consumption, *D. edulis* provides an important income, being ranked among the top three species for commercial value in all four communities (Mbosso *et al.* in prep.). In terms of value, this is more important for women, for whom the marketing of safou fruit is one of the few relatively independent sources of income they have, but the timing of the income (July–September) is also important for men, coming at a time of year when they have few other income sources and school fees are due. Over 90% of *D. edulis* trees occur in the perennial crop farms (mainly cocoa and coffee), which constitute the predominant land use in the area. In addition to provision of shade, *D. edulis* plays an important role as an income buffer when cocoa and coffee prices fall (Schreckenberg *et al.* 2002).

Tenure is not an insurmountable constraint to planting safou as most households have at least some land with secure tenure. Nor is labour a particular problem as tree-planting and maintenance work is integrated with that required for other tree crops. Bottlenecks may occur at harvest time, but in communities such as Chopfarm, proximity to flourishing *D. edulis* markets (e.g. Gabon and Douala) means that farmers no longer need to invest much labour in harvesting or marketing as outside wholesalers bring in their own labour to harvest whole trees (Schreckenberg *et al.* 2002).

The most popular indigenous fruit tree in the southern Nigerian study sites was *Irvingia gabonensis* (bush mango / dika nut), which is widely planted in homegardens and, to a lesser extent, in food crop fields (Degrande *et al.* in prep.). The fresh fruits are eaten as a snack while the dried kernel is ground and added to sauces to make them viscous. The sliminess (or 'drawability') of the resulting sauces is particularly valued. In southern Cameroon, very few trees of this species are actually planted at present, although naturally regenerating seedlings are protected. Nevertheless, farmers in Nko'ovos II ranked *I. gabonensis* as the most important species for food and commercial value (Mbosso 1999; Mbosso *et al*. in prep.). Farmers expressed interest in the cultivation of *I. gabonensis* because of greatly increased interest from traders in recent years (Degrande *et al.* in prep.).

Improved market access would enhance communities' opportunities to cultivate and sell indigenous fruits of all species. Similarly, improved market information systems would improve the opportunities to generate income. These systems should be targeted first and foremost at women, for whom the *D. edulis* trade, for example, is particularly important (Awono *et al.* 2002).

Characterisation of intra-specific variation in fruit and kernel characteristics

This section of the paper presents the results of a study in West and Central Africa to quantify the tree-to-tree variation in fruit characteristics in *Dacryodes edulis* and *Irvingia gabonensis*. The study was carried out in conjunction with the socio-economic research described above and within the context of a participatory tree domestication programme managed by the International Centre for Research in Agroforestry (ICRAF)[2]. Its purpose was to identify combinations of fruit traits that could be brought together through 'plus-tree' selection and then captured as a 'cultivar' by vegetative propagation.

The assessment of tree-to-tree variation in the *I. gabonensis* and *D. edulis* populations in Cameroon and Nigeria was aimed at the determination of:

- the levels of diversity available to farmers within the area of their communal ownership,
- the levels of selection intensity being applied by farmers,
- the level of market recognition of variability in fruit or kernel traits.

METHODS

This study is based on data collected from six villages (Table 1), four in Cameroon (Atangana *et al.* 2001, 2002; Waruhui 1999; Waruhui *et al.* in prep.) and two in Nigeria (Ukafor 2002; Anegbeh *et al.* in press a/b). The sites were chosen to represent a range of ethnic, social and environmental factors found in the region. These sites were separated by 100–350 km and hence are clearly different populations. The use of three geographically distinct sites should reduce the chance of finding correlated traits that may be due to random non-general associations that can occur in a single isolated population. Two of the sites (Nko'ovos II in Cameroon and Ugwuaji in Nigeria) were in fact within the genetic diversity hotspots of *I. gabonensis,* identified by Lowe *et al*. (2000), using DNA markers, each with genetically distinct populations.

Diameter at breast height (dbh) was measured for each tree, while tree height was estimated. Tree-to-tree variation in fruit and kernel characteristics were assessed in all the trees of a randomly selected, discrete population of up to 100 trees per village, depending on availability. Measurements were made of the following eight fruit traits in 24 randomly collected ripe fruits per tree of *I. gabonensis* and *D. edulis*, using kitchen scales accurate to 2 g and calipers accurate to 0.1 mm (see Leakey *et al.* 2000):

- Fresh fruit mass (g),
- Nut mass (g) – for *I. gabonensis* only – after drying the residue flesh,
- Fresh kernel mass (g),
- Fruit length (mm),
- Fruit width (mm),
- Flesh depth in the fruit breadth dimension (mm),
- Taste score (1[bitter]–5 [sweet]),
- Fibrosity score (1 [low fibre]–5 [high fibre]) – for *I. gabonensis* only.
- Oiliness score (1 [low oil] – 5 [high oil]) – for *D. edulis* only.

Taste, fibrosity and oiliness were assessed by the same people at each site. The owners of the trees were asked whether or not the tree had been planted and questioned

TABLE 1 *The location of study villages and the numbers of trees assessed*

		Latitude	Longitude	Altitude	Number of trees assessed
I. gabonensis					
Cameroon	Elig Nkouma	4°06'N	11°24'E	460 m	31
	Nko'ovos II	2°55'N	11°21'E	610 m	21
Nigeria	Ugwuaji	6°25'N	7°32'E	175 m	100
D. edulis					
Cameroon	Makenene	4°52'N	10°48'E	580 m	100
	Elig Nkouma	4°06'N	11°24'E	460 m	57
	Nko'ovos II	2°55'N	11°21'E	610 m	12
	Chop Farm	3°57'N	9°15'E	11 m	31
Nigeria	Ilile	5°19'N	6°55'E	54 m	100

about the tree's fruiting behaviour. The farmers were also asked about the likely market price of each fruit sample.

The above data were used to derive: Shell mass (g) (= Nut mass – kernel mass, for *I. gabonensis* only), and fresh Flesh mass (g) (Fruit mass – Nut mass, in *I. gabonensis*, and Fruit mass – Kernel mass, in *D. edulis*). Since the ease with which nuts can be cracked to allow kernel extraction is seen by farmers as an important trait, a shell brittleness score was derived as 50 minus shell mass (so that the desirable trees for selection had a high score).

The kernels of *I. gabonensis* are used as a thickening agent in traditional soups and stews in West and Central Africa. To assess the tree-to-tree variation in these properties, kernels were stored for analysis (Leakey *et al.* in press). This analysis was done using a Rapid Visco-Analyzer to determine changes in the physical properties of each sample of de-fatted dika nut meal in water, so mimicking the changes occurring during the cooking process. Traces, generated during a 15-minute two-phase temperature profile (a "cooking phase" at 95°C and an "eating phase" at 50°C), recorded the electrical energy consumed to maintain constant stirring speed of a paddle in the paste. Two food thickening parameters were derived from the final two minutes of the trace at eating temperature: (i) the average value, taken as the "viscosity" (magnitude of soup thickening) and (ii) the presumed "drawability", which was based on the varying spikiness (width) of the trace. The latter is proposed as the ability of the gum to exert periodic viscoelastic restraining forces on the paddle; this is presumed to reflect its ability to be drawn out into tendrils with a spoon.

RESULTS AND DISCUSSION

The relationships between tree height and dbh indicated that the Cameroon and Nigerian populations of *I. gabonensis* differed in demographic structure (Atangana *et al.* 2001; Anegbeh *et al.* in press a/b), with the Cameroon population reflecting a mature age, while the Nigerian population was much younger. These differences can be explained by the farmers' information which revealed that the Cameroon population was made up of unplanted natural trees retained when forest was cleared for agriculture, while the Nigerian population was made up of planted trees.

1. The levels of diversity available to farmers within their community

Contrary to the suggestion that there are morphologically distinct 'varieties' in the on-farm populations of *D. edulis* (Okafor 1983), this study found continuous variation in all the traits examined. There was, however, highly significant ($p < 0.001$) variation between individual trees for each trait, and as expected, trees with superiority in one trait (*e.g.* fruit size) are not necessarily superior in other traits (*e.g.* fruit taste). Consequently, the chance of finding trees with superiority in two or more traits is considerably lower than for a single trait. Nevertheless, it is highly desirable to identify combinations of traits, which should be brought together for cultivar development. To pursue this objective of defining combinations of desirable traits, an 'ideotype' approach has been developed.

In *I. gabonensis*, an examination of all the data (Figure 1) indicates that there are some trees (Ug10, Ug75, Ug12) with high values for fruit traits (fruit length, fruit width, flesh weight, flesh depth and taste) that are close to the 'fruit ideotype' (solid black line), and thus superior as fruit for eating fresh. In the same way there are other trees (EN26, Nk28, Nk31, Nk6) with kernel traits (kernel weight, shell brittleness) close to the kernel ideotype (solid black line). Interestingly, however, the study of the physical and chemical properties of the kernels (Leakey *et al.*, in press b) found that none of the trees assessed had high values for both of the food thickening traits (viscosity and drawability). Furthermore, the viscosity and 'drawability' of the polysaccharide extract were poorly related traits (e.g. $r^2 = 0.336$) and thus probably kernels from different trees

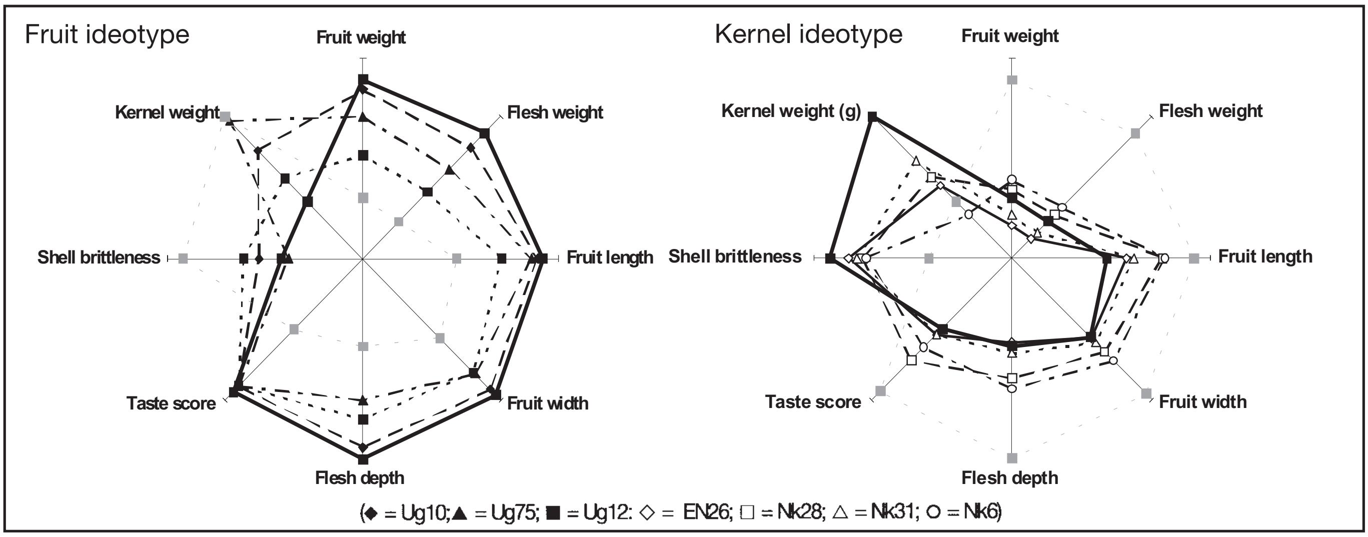

FIGURE 1 *Fruit and kernel ideotypes for* I. gabonensis*, compared with the data from the best trees*

have different uses in food preparation. Consequently, depending on the use of the kernels, the kernel ideotype should be sub-divided into two food-thickening sub-ideotypes, one with good properties for viscosity, and the other for drawability (Leakey *et al*. in press b).

Fat determination and fatty acid profiling of kernels confirmed previous studies (see review by Leakey 1999b) that fat content ranges from 50–70% between samples, although the range in individual tree samples in the present study was greater than this (37.5–75.5%). As also found elsewhere, the study identified myristic acid and lauric acid as the major fatty acid components of the extracted fat. Thus, it appears that kernels for vegetable oil production may have to conform to a third ideotype, depending on the yield and desirable properties of the oils.

To date, the range of nutritional values of *I. gabonensis* kernels has not been reported to vary between samples, although reported protein content of different samples has ranged from 14.3–24.1% (Leakey 1999b). However, it is clear from a protein analysis of de-fatted kernel samples from six trees, selected for their diverse viscosity properties, that they were similar to the published range. Thus study of more trees may determine opportunities to further select individual trees for their nutritional value. Electrophoretic analysis of total protein extracts according to molecular weight, demonstrated that all six samples had similar protein patterns.

In *D. edulis*, the fruits for eating as a nutritious cooked vegetable would appear to fit a single ideotype characterised by large size, thick flesh and a small kernel. Further refinement of this ideotype may follow once the organoleptic properties of these fruits are better understood. A preliminary study by a trained tasting panel has found that there is variation in acidity, astringency, bitterness, sourness, as well as in fibrosity, (Kengni *et al.* 2000; Leakey *et al.* 2002). Thus, taking all these traits together, the morphological and organoleptic studies to date suggest that there are opportunities, through ideotype selection, for the development of cultivars that combine large size with good quality attributes for the fresh fruit trade. However, there are also potential industrial uses of these fruits for vegetable oils (Kapseu and Tchiegang 1996; Silou *et al*. in press), which may require further refinement of the fruit ideotype, depending on the oil properties required.

For both species, the above definition of ideotypes feeds into the on-farm domestication process, by helping researchers to explain to NGOs and farmers what traits, or combinations of traits (ideotypes) are available for selection and thus their opportunities for cultivar development. The inclusion of this information into the community domestication programmes could have very rapid impacts on the level of genetic gains achieved by farmers in the next ten years. For example, fruit size could probably be increased 2–3 fold by creating cultivars that conform to the 'fruit ideotypes'. Since different villages will create different sets of cultivars for each species they wish to cultivate, intra- and inter-specific diversity will be maintained at the farm level, at least in the short-to-medium term.

The study has also identified some variation in the fruiting phenology of different trees, illustrating opportunities for selection for the seasonality of production. Seasonality is not a problem in the case of *I. gabonensis* as the storage of dika nuts allows a year-round market, but the fruits of *D. edulis* have a very short shelf life and thus there is a need to extend the productive season, as for example with the recently created 'Nöel' cultivar that fruits at Christmas (Tchoundjeu *et al*. unpublished). Alternatively, research is needed to develop storage and/or processing techniques for the fruits that can be used in the villages or local towns.

An additional advantage of the ideotype approach is that the cultivars may have a broad genetic base in many other characteristics, especially if the cultivars come from unrelated populations. This could make them less susceptible to pest and disease outbreaks (Leakey 1991). To minimise the risks of narrowing the genetic base and associated disease and pest problems, it would also be wise to ensure that there is a turnover of recommended cultivars arising from an on-going and continuous programme of selection.

2. The levels of selection intensity being applied by farmers

In an attempt to determine the levels of tree selection by farmers, the frequency distributions of the data for each measured trait were plotted and examined. The results did not provide an answer. However, an assessment of the genetic gain made by farmers through their own selection efforts was achieved.

Typically, trees are out-breeding and genetically very diverse due to the contribution of large numbers of individuals to a shared genepool and the free segregation of allelles during meiosis (Zobel and Talbert 1984), typically resulting in normally-distributed variation of quantitatively-inherited polygenic traits. These patterns of intraspecific variation mean that for any one trait there are relatively rare genotypes which display the desired set of characteristics; so called 'plus-trees'. In addition, it is well known that tree populations from geographically different locations (provenances) can have different mean values. Leakey *et al.* (in press) have postulated that when data from different wild populations for a given trait are combined, the overall population will also be normally distributed. In plant breeding, cycles of selecting and crossing between only the best individuals in the population (truncated selection), result in new progenies, which outperform their parents in the selected trait (Futuyma 1998). The degree of improvement depends on the narrow sense heritability (Stearns and Hockstra 2000). The domestication of a species must therefore result in changes in the frequency distribution of the values of the selected trait among the members of the population (and typically an increasing reduction in diversity within the selected population, due to an increasing selection intensity). During the course of several generations of truncated selection, the frequency distribution of the trait can thus

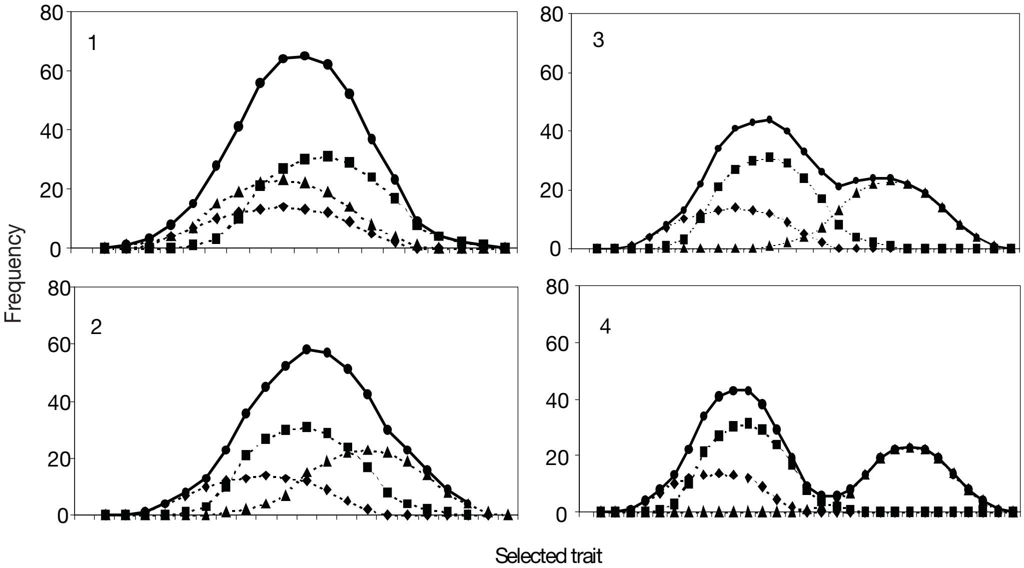

FIGURE 2 *Stages of domestication: a hypothesis (1 = wild, 4 = a variety formed by selection, stages 2 and 3 are indeterminate)*

be expected to change through a progression of stages that ultimately lead to the formation of a variety.

To determine if the stage of farmer-selected domestication reached in different populations of *I. gabonensis* and *D. edulis*, Leakey *et al*. (in press) have hypothesised that when, over a long period of time, farmers take and plant seeds from the fruits of their best trees, the frequency distribution of data for the selected trait will change from normal (stage 1), to positively skewed (stage 2), to a flattened normal distribution again (stage 3), to negatively skewed (stage 4) to normal (stage 5) – see Figure 2. With each stage there is also a progressive shift along the x axis, as the progeny is improved for the selected trait. In contrast, the frequency distribution for neutral traits (unselected traits with no correlation to the selected trait) will remain at stage 1.

In *D. edulis* for most traits, the frequency distributions of individual populations were close to normality although there were differences between the traits, with regard to the degree of separation between the populations along the x axis. For example, the peak mean kernel mass of all populations was the same, while for flesh thickness, fruit mass and fruit width, especially in the Makenene and Elig Nkouma populations from Cameroon, there were considerable differences in the peak mean (i.e. they were distributed along the x axis). Since the kernel of *D. edulis* is usually discarded, as being of little value, while the mass and size of the fruit and the thickness of the flesh are all indicators of a desirable fruit, it seems likely that over time there has been intentional selection by Cameroon farmers for these desirable traits, resulting in domestication progressing to between stages 2 and 3. Because the mean flesh thickness of the selected population is greater (7.5 mm) than that of the wild population (4.5 mm), these data suggest that farmers have made a 67% genetic gain in flesh depth. Similarly in *I. gabonensis*, evidence for domestication through the selection of large-fruited trees, was found in the population from Ugwuaji, in Nigeria. In this species, domestication seems to have advanced to stage 2, with a genetic gain of 44% in flesh depth. There was no evidence for differences in the stage of domestication between sub-populations in Cameroon. The fact that subsistence farmers have domesticated these fruit to this point emphasises the importance that they attribute to indigenous fruits for their own consumption and for trade.

The recognition that farmers in Cameroon and Nigeria have initiated the domestication of two of their indigenous fruit trees emphasises the importance of the current activities to further domesticate the indigenous trees that provide marketable non-timber forest products of importance to local people for food security and income generation. The need now is to go to the next stage of domestication (Figure 3) in which cultivars are developed, using vegetative propagation techniques (Leakey *et al*. 1990; Shiembo *et al*. 1996), from the very best trees available in each village. This is starting in the West African participatory tree domestication programme (Tchoundjeu *et al*. 1998) with the intention of using these cultivars in cocoa and other agroforests to diversify the agroecosystem. In this way, it is envisioned that it may be possible to create land use systems that enhance the livelihoods of poor subsistence farmers (Leakey 1999b). In addition, the domestication of these species may lead to the creation of export commodities to diversify both the farmers and national economies. These benefits, together with the international public goods and

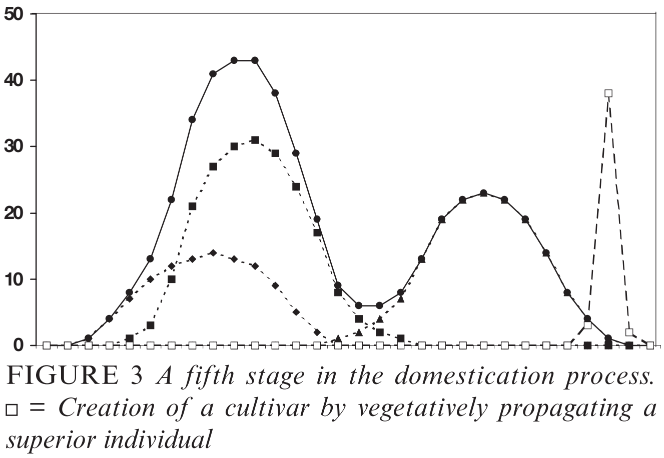

FIGURE 3 *A fifth stage in the domestication process.* □ = *Creation of a cultivar by vegetatively propagating a superior individual*

services (carbon sequestration, biodiversity, *etc*.) that can be derived from increasing the numbers of trees in agroecosystems, are outcomes that could benefit the global community (Leakey 2001).

3. The level of market recognition of variability in fruit or kernel traits

The importance of indigenous fruits in West Africa is emerging from market studies, which indicate that, for example with *D. edulis*, wholesale traders in Gabon travel to markets like Makenene to buy fruits for importation into Gabon. Similar evidence of regional trade has recently also been documented for *I. gabonensis* and *Ricinodendron heudelotii* kernels, and the nuts of *Cola* spp. (Ndoye *et al*. 1998; Ruiz Pérez *et al*. 1999).

To determine if these markets reward farmers for producing fruits with desirable characteristics, fruit samples were purchased at the peak of the season (3–17 August 2000) from urban (Mfoundi, Yaoundé) and rural (Makenene Centre and Makenene East) markets in Cameroon (Atangana *et al.* in press; Leakey *et al*. 2002). The area around Makenene has a reputation for producing and selling *D. edulis* fruits, leading to the existence of a retail market (Makenene East) and one of the largest wholesale markets in the country (Makenene Centre). The fruits of each sample were characterised as described in the 'Methods' section.

Statistically significant differences in each fruit trait were found between samples for each market, but the relationships between fruit traits and prices were found to be weak in wholesale markets. However, in retail markets, fruit mass, length and width were positively correlated with price per fruit, indicating that small-scale traders can benefit from consumers' preferences for large fruits. Interestingly, the relationship between fruit mass and price was stronger in the urban Mfoundi market than in more rural Makenene East market, suggesting that consumers in urban markets will pay more for large, tasty fruits than they will pay for small or less tasty fruits.

It seems therefore that at present farmers who typically sell their produce in rural wholesale markets are not currently being rewarded for producing superior fruits, although big fruits, which have the most pulp, fetch the highest prices in retail markets. This indicates that retailers, who are in closest contact with consumer demands, take into account phenotypic variation in fruit size when fixing market prices. There is also some evidence that some other qualitative traits (e.g. flavour) are also recognised by urban retailers as Leakey and Ladipo (1996) found that while big fruits tended to have high market prices, some small fruits were also highly priced. Similarly, Waruhiu (1999) found that a relatively uncommon white skinned fruit type was more expensive than similar sized fruits of the common purple colour. Wholesalers on the other hand, do not appear to take the characteristics of individual fruit types into account when pricing fruits. It is to be hoped that in the future, farmers producing fruits of named cultivars will be rewarded with higher prices.

Impact and strategic importance

In these and other indigenous fruits (e.g. *Sclerocarya birrea*), intra-specific variation is typically found to be greatest at the village level, thus there seems to be several strategic advantages of tree domestication at this level. Firstly, it gives each community the opportunity for significant genetic gain without empowering one community more than its neighbours. Secondly, this village-level, self-help approach to domestication also helps to maintain a broad genetic base within the species being domesticated, as each village will develop a different collection of cultivars. Furthermore, it allows the farmers to practice their new skills on any other species of interest to them, and so does not restrict the domestication process to the priority species. In the long-term, this will promote the species diversity of their farming systems. In terms of ensuring impact from development assistance, this approach of working directly with farmers has the advantage that the project outputs are immediately disseminated into the target population, thus overcoming the delays that often arise from a research station stage in the domestication process.

Potential for wider application of participatory domestication

The domestication of new species is a major undertaking, one that is a continuous process of improvement and one that has to be justified by the benefits that accrue to the producers and consumers of the products. There is currently some debate among development organisations focused on poverty alleviation, sustainable livelihoods and food security, about the direction for future research: some favour biotechnology and an expansion of the Green Revolution (McCalla and Brown 1999; Lipton 1999), while others see potential for broadening the basket of crops (McNeely and Scherr 2001) – a Really Green Revolution (Leakey 2001). In the case of a number of agroforestry trees, including *Irvingia gabonensis* (Aubry Lecomte ex O'Rorke) Baillon. and *Dacryodes edulis* (G.Don) H.J. Lam, it has been argued that their domestication will enhance farmer livelihoods, reduce poverty, and promote economic development (Leakey 2001). At the same time, this domestication of agroforestry trees should provide farmers with an incentive to integrate trees into their farming systems, so developing an agroecological succession which can progress to maturity (Leakey 1996). In this way, it has been suggested (Leakey 1999a), that the domestication of indigenous fruits could encourage the development of sustainable agroforestry practices that rehabilitate degraded farmland, sequester carbon and other greenhouse gases and enhance both biodiversity and the functioning of agroecosystems. Through the enhanced income generation arising from indigenous fruit trees, farmers have the opportunity to buy fertilisers and other agricultural inputs, and so to raise the productivity of their staple food crops from the normally low yields, up towards their biological capacity. In this way, farmers can perhaps reap the benefits from the Green Revolution.

We believe that the experience of domesticating indigenous fruit tree species in West Africa is relevant to many other regions of the tropics, because throughout the tropics:

1. There are many tree species producing edible fruits and other products, which are grown and marketed on a small scale and which are potential candidates for domestication. The range of available species, allows for the choice of those that meet labour availability, different markets, systems of tenure, variations in soils and climate, etc.
2. There is a decline in the availability of traditionally important forest products from wild sources, especially near urban markets.
3. There is great interest in agroforestry as a low input, low-risk, sustainable farming system, which supports rural livelihoods.
4. There are many small-scale subsistence farmers who are poor and need opportunities to generate income.
5. There are risks arising from falling cash crop prices, pests and diseases, increasing environmental pressures, which could be averted by economic and ecological diversification.
6. It could build on and enhances the local social and cultural traditions
7. It could promote small-scale local processing and entrepreneurial activity at the community level.
8. It could benefit and empower women who are often involved in the labour intensive harvesting, processing and marketing of forest fruits, and who play a strong role in managing home gardens and village nurseries.
9. It could enhance the health of the rural and urban communities, as indigenous fruits are rich in minerals, vitamins, protein, oils and carbohydrates and so can also meet the needs of poor people for food and nutritional security.

Finally, the participatory approach to domestication is a relatively rapid and low cost option to development, which given the need to domesticate a wide array of species, cannot be achieved by the "Green Revolution" approach to agricultural development.

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