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DOMESTICATION OF *DACRYODES EDULIS*: STATE-OF-THE-ART

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ABSTRACT

Dacryodes edulis is one of the important local fruit tree species of West and Central Africa. This paper reviews the activities of a regional programme to domesticate high-value indigenous fruit trees in the region. This programme is coordinated by the International Centre for Research in Agroforestry (ICRAF) and implemented in Cameroon in collaboration with the Institute of Agricultural Research for Development (IRAD), National Agricultural Extension and Research Programme (PNVRA) agents and NGOs and universities of the region. It is based on a participatory approach to domestication that is in marked contrast to that of food crop domestication under the Green Revolution. The participatory process with farmers started with priority setting between species, progressed to germplasm collection and the establishment of village nurseries for clonal propagation of superior trees, and is currently involved in the selection of superior trees for cultivar development. Work is also in progress on post-harvest processing, market development and the integration of cultivars into agroforestry systems.

Key words: Safou, *Dacryodes edulis*, domestication, vegetative propagation, marcot, germplasm collection, cultivar development, phenotypic selection, community nurseries.

RESUME

Dacryodes edulis est l'une des plus importantes espèces fruitières arboricoles de l'Afrique de l'Ouest et du Centre. Le présent article passe en revue les activités du programme de domestication des arbres fruitiers locaux à grand potentiel dans la région. Sous la coordination du Centre International de Recherche en Agroforesterie (ICRAF), ce programme est réalisé avec la collaboration de l'Institut de Recherche Agricole pour le Développement (IRAD), du Programme National de Vulgarisation et de Recherche Agricoles (PNVRA), des ONGs et des Universités de la région. Il est basé sur une approche participative à la domestication, ce qui contraste grandement avec la domestication des plantes vivrières de la Révolution Verte. Le processus participatif avec les paysans a débuté par la prioritisation des espèces, suivie par la collecte de germoplasme et l'établissement des pépinières paysannes en vue d'une propagation clonale des "arbres supérieurs". Actuellement, ce processus est orienté vers la sélection des "arbres supérieurs" pour le développement des cultivars. Des travaux sont aussi en cours sur la technologie post-récolte, la commercialisation et l'intégration des cultivars dans les systèmes agroforestiers.

Mots clés: Safou, *Dacryodes edulis,* domestication, propagation vegetative, marcotte, collecte de germoplasme, développement de cultivars, sélection phénotypique, pépinières communautaires.

INTRODUCTION

The West and Central African region is characterised by a growing season of 271–365 days, with annual rainfall ranging from 1400 to more than 4000 mm. Over 80% of food crops (cassava, maize, yam, plantain and cocoyam) produced in the region are grown by small-scale subsistence farmers, who typically use traditional shifting cultivation systems. Long fallow periods are required to restore soil fertility, suppress weeds and reduce pest and diseases. However, increasing population pressure and rural to urban migration of the work force have reduced the fallow period to less than five years in most areas, with consequences of soil degradation, reduced nutrient cycling in soils, etc. These subsistence farmers often grow small areas of cocoa and coffee under the shade of larger trees. Since the late 1980s, the world market price for the region's major cash crops has dropped significantly. This, coupled with the devaluation of the local currency in French speaking countries, has resulted in accelerated forest clearing, loss of biodiversity, increased poverty and lower quality of life both for rural populations and the urban majority. Nevertheless, the degraded forest has tremendous potential. It is endowed with high-value fruits and medicinal plants, which are currently traded locally as well as in regional and international markets. Unfortunately, they are mostly exploited from the wild and, until recently, there has been little or no focused research effort to domesticate and cultivate them, or to improve their genetic base.

The domestication of traditionally important indigenous trees has recently become a major programme in international agroforestry research (Sanchez and Leakey 1997). Their commercial importance has led farmers to identify these local species as candidates for domestication through agroforestry (Franzel *et al*. 1996), and to the initiation of a domestication programme for indigenous fruit and medicinal trees (Simons 1996, Leakey and Simons 1998, Tchoundjeu *et al*. 1998). *Dacryodes edulis* (G. Don) H.J. Lam, also known as safou or African plum, in the Burseraceae, is one of these candidate species. The present paper reviews the current state of this domestication programme, with particular emphasis on safou. Non-timber forest products from safou and a few other species constitute an important source of revenue for the region. In 1997, the trade of safou in Cameroon alone was worth about US$7.5 million (Awono *et al.* 2002). In the international market, Tabuna (1999) has reported that 105 tonnes of safou fruit are exported every year from Central Africa to Europe. Of this, Cameroon produces 100 tonnes and the Republic of Congo and the Democratic Republic of Congo produce 2 and 3 tonnes respectively.

There is some confusion with regard to the natural range of safou, which Vivien and Faure (1985) and Keay (1989) have indicated to be limited to SE Nigeria, while others have reported it to range from Uganda to Sierra Leone (Troupin 1950), or Cameroon, Gabon, Congo and Equatorial Guinea (Aubreville 1962). The species is, however, now distributed widely in Central Africa in farmers' fields, but nothing is known about the history of this distribution, if indeed it is not indigenous to the region. A molecular ecology study could determine the genetic structure of the population and resolve this uncertainty.

Safou is mainly cultivated for its nutritional and market values. Locally prices are about US$1per kg of flesh, but on the international market whole fruits fetch from 350BF (US$7)/kg in Brussels to FF40 (US$5)/kg and FF50 (US$6)/kg in Paris and Lyons. The mesocarp, which is eaten raw, boiled in water or roasted, is an important source of lipids and proteins. The oil content of the fresh pulp varies between 33 and 65% depending on the variety and the state of maturity (Omoti and Okiy 1987). Kiamouama and Silou (1987) have characterised the lipid fraction as consisting of mainly palmito-oleic acids with 47.33% of palmitic acid (C16:0), 27.35% of oleic acid (C18:2) and 20.46% of linoleic acid. The high content of fatty acids combined with its amino-acid content makes safou an alternative source of vegetable oils for the food, pharmaceutical and cosmetic industries.

Despite some existing studies on safou (Okafor 1983, Nya Ngatchou and Kengue 1986, Kengue and Schwendiman 1990, Kengue 1996, Leakey and Ladipo 1996, Ayuk *et al.* 1999) more research is needed to provide the data on which to base the domestication, large-scale cultivation and genetic improvement of this important species. The provenance collections made by Cameroon's Institute of Agricultural Research for Development (IRAD) 12 years ago have, however, provided knowledge about phenology, growth and yield (Kengue and Singa 1998). They have also served as a stock of material for propagation. This has led to the establishment of the first series of clonal variety trials on station and on farms (Kengue *et al.* 1998). The present paper reviews current activities towards the domestication of safou with active participation of farmers of Southern Cameroon and Nigeria.

PROGRESS ON DIFFERENT ASPECTS OF PARTICIPATORY DOMESTICATION

The domestication of safou is constrained by a limited knowledge base, since the existing literature has focussed on reproductive biology (Kengue 1990), chemical analysis (Silou 1991) and management and economic potential (Ayuk *et al.* 1999). Furthermore, there is a need for a novel strategy as the domestication of most plants is based on the needs of agricultural/horticultural crops, or industrial forest species, grown in large-scale monocultures in northern-temperate countries. These are not appropriate for agroforestry trees in the tropics. The domestication of these species needs to take into consideration the requirements of small-scale, resource-poor farmers and their subsistence farming systems. Consequently, the International Centre for Research in Agroforestry (ICRAF) and its partners in West and Central Africa are developing a new and more participatory approach to the domestication of high-value agroforestry tree species based on: priority setting by farmers, germplasm collection, low-technology vegetative propagation in village nurseries, the genetic characterisation of the marketable products for consumption and processing, the integration of the species into agroforests managed by subsistence farmers and the expansion of markets for the products. This participatory approach to domestication is innovative and fundamentally important because it meets the

needs of local farmers and conforms to the requirements of the Convention on Biological Diversity (CBD), by allowing farmers to maintain the rights to their indigenous knowledge and their genetic material. It also creates a model for domestication, which is in marked contrast to the approach of the Green Revolution, which was the prerogative of well-funded international research centres. The Green Revolution model is also inappropriate for the large numbers of agroforestry tree species, because it is very unlikely that international funds will be made available on an adequate scale for species, which will not individually become major cash crops. Consequently, a self-help approach for farmers that will allow them to undertake their own domestication programme is much more relevant. This more appropriate model could result in improvements in a very wide array of species of local or regional importance to the livelihoods of poor farmers practising subsistence agriculture.

Priority setting

The first step in participatory tree domestication is the determination at village level of which species should receive priority for genetic improvement. This important step of priority setting has already been widely reported (Jaenicke *et al.* 1995, Franzel *et al.* 1996). It involves integration of researchers' and farmers' perspectives, taking into consideration market and genetic potential for choosing the species that will give the greatest benefits and improve resource-poor farmers' conditions. The priority setting process was first conducted in four countries (Cameroon, Gabon, Ghana and Nigeria) of West and Central Africa, and revealed the great interest of farmers of the region for their indigenous fruit trees. Safou was ranked second on the priority list for the Humid Lowlands of West Africa (Table 1).

Currently the focus of the ICRAF/IRAD tree domestication programme is on the top five priority species, *Irvingia gabonensis* (Bush mango / Dika nut), *D. edulis* (Safou / African Plum), *Ricinodendron heudelotii* (Njangsang), *Garcinia*

TABLE 1

Priority tree species selected for domestication by implementation of farmer preference surveys and priority setting guidelines (Franzel *et al.* 1996) by ICRAF and partners

	Humid lowlands of West and Central Africa
Priority order	
1	*Irvingia gabonenis/ I.wombolu*
2	*Dacryodes edulis/D. klaineana*
3	*Ricinodendron heudelottii*
4	*Chrysophyllum albidum*
5	*Garcinia kola/G. afzelii*

kola (Bitter kola), and *Chrysophyllum albidum* (Starapple). To this list have been added some medicinal plants of commercial importance (*Prunus africana* and *Pausinystalia johimbe*) because of opportunities to increase farmer income, fears about the future of the resource for industry, and the perceived needs for conservation of the species in their natural habitat.

Germplasm collection

Rangewide germplasm collection is the second step in tree domestication, and is both expensive and time consuming. Maintaining the genetic diversity of a species is essential to its domestication and the maximum amount of diversity should be present in the collected germplasm. The collected material can be distributed to users (farmers, horticulturists) for widescale planting. For safou the germplasm collection strategy has primarily targeted the identification of superior trees of immediate benefit to farmers, as existing provenance collections by IRAD (Kengue 1990) provide some conservation of genetic diversity. Consequently, the main activity has been to work together with farmers to identify, select and collect germplasm (seeds and marcots) from superior trees. This activity has been centred on four sub-regions in Cameroon (Mbouda and Kekem in West Province, and Boumnyebel and Makénéné in Centre Province. These sub-regions were chosen as they are likely to cover the geographical range and the different uses of safou. The collections focus on both mature fruits and rooted marcots (air layering) set at the beginning of the rainy season.

Seed collections

Seed collection involved detailed planning and extensive training of field teams in Cameroon, Equatorial Guinea, Gabon and Nigeria, and then, through Material Transfer Agreements, the exchange of the germplasm between these countries for the establishment of live regional genebanks. In each selected village, farmers identified 20-30 trees with desirable fruits and kernel traits, with the restriction that not more than 10 trees should be chosen from any one farm. Participating villages were separated by at least 25 km. Further selection by the collection team (ICRAF scientists, NARS, NGOs and farmers) narrowed the number down to two trees per village. During the collection, a GPS (Geographical Positioning System) was used to record the position of the tree for future reference. In addition, information on the age of the tree, the frequency and the duration of fruiting were requested from the owner of the tree. All seed collections are identified, through the identity number given to each tree, with the farmer owning the tree, to ensure that his or her rights are secure under the CBD. More than 3000 seedlings are currently being raised in nurseries for the establishment of regional genebanks and for subsequent vegetative propagation.

Collection of marcots for cultivar development

Marcots were collected from the Cameroon sites mentioned above. In 1998, at the beginning of the rainy season (May-June), a maximum of 10 marcots on each selected tree was jointly set by a team consisting of ICRAF and NGO staff and farmers. During the marcot setting, farmer selection criteria, identity of farmers and other normal germplasm passport data (exact location of the tree using GPS, soil and tree characteristics) were recorded. Marcots were mainly set on younger, more accessible, trees with a history of several years of productive fruiting, to enable meaningful selection. Marcots were set on the same branch class (3–5 cm diameter) and approximately at the same position in the middle of the canopy, with a similar light environment. Three or four months later, the rooted marcots were harvested and labelled to record the farmer's identity. Sixty percent of the rooted marcots were taken back for weaning in the on-station nursery, while 40% were left with the farmers for weaning in a village nursery. This division of the rooted marcots between the stations and the farmers is to maximise the chances that each genotype is successfully propagated, without jeopardising farmers' property rights. It also ensures that the genetic diversity of the selected on-station germplasm collection, and any germplasm exchange between villages, is maximised. Moreover, the on-station material can be used to replenish the village stock in case of any losses.

Currently, safou marcots have been planted in demonstration plots in eight pilot villages in Southern Cameroon and two pilot villages in South East Nigeria, while marcots taken to the station have been planted in 3 ha of experimental plots at Minkoameyos near Yaoundé to assess their performance in different cropping systems. In the villages, these plantings also serve as demonstration plots to show that they fruit earlier than plants established from seeds or juvenile cuttings, and that they are genetic 'copies' of their mother plant. Some marcots have also been established as stockplants for subsequent mass production using stem cuttings.

Provenance and reproductive biology

Provenance trials involving 20 accessions of safou from the western highlands and humid forest lowlands of Cameroon were established in September 1995 by IRAD. These accessions are being grown in the Barombi-Kang and Yaoundé research stations. The study had three main objectives: safeguarding the genetic diversity of safou, systematic characterisation, and the evaluation of production by different accessions. Results obtained so far have shown important variation between accessions and between individual trees within the same accession (Kengue and Singa 1998).

Research has also been carried out into the reproductive biology of safou, based on field and laboratory observations. The results indicate that safou is a dioecious species with an allogamous reproduction system (Kengue *et al*. 2002). The species is insect-pollinated with bees (*Apis mellifera*) being the main pollinator. This type of reproduction results in great population heterogeneity.

Vegetative propagation techniques

Vegetative propagation techniques are indispensable for the capture and multiplication of the phenotypic variation expressed by superior individuals with desirable characters. Leakey and Simons (2000) have listed eight situations when the use of vegetative propagation is appropriate in tree domestication. Six of these situations apply to the domestication of safou:

- the tree has extensive tree-to-tree variability and rare individuals have fruits that combine several desirable traits;
- high uniformity is required in the fruit crop to meet the market specifications;
- the high value of the crop warrants the extra expense to ensure a high-quality product;
- there is an urgent need to shorten the timescale for the achievement of domestication below that achievable through breeding;
- seed viability is limited to a short season; and
- knowledge of proven traits is available from farmers.

Vegetative propagation of trees can be done using a variety of techniques: - rooting juvenile stem cuttings, grafting, budding, layering and *in vitro* tissue culture. None of these techniques are well developed for the indigenous fruit trees of West and Central Africa. As early as 1957, Philippe tried to propagate safou vegetatively, but he reported that cuttings were difficult to root. Currently, however, grafting, marcotting and the rooting of stem cuttings are being used with some success. The use of single node cuttings (a portion of a stem with a leaf and axillary bud) set in a high-humidity, non-mist, polyethylene propagator has been found to be successful for many tropical trees (Leakey *et al.* 1990, Tchoundjeu and Leakey 1996). In this volume, Mialoundama *et al*. report good rooting (60-80% in 6–8 weeks) with juvenile cuttings, using non-mist propagators. To implement these techniques of clonal propagation, farmers are being helped to develop simple and inexpensive village nurseries and are being trained in vegetative propagation. With this 'self-help' approach to domestication and these nursery skills, farmers will be able to develop cultivars from the best safou and other fruit trees in their village to meet their domestic needs and local market demands.

Characterisation of safou

As part of a wider study to examine the constraints to tree domestication (Schreckenberg *et al*. 2001), studies to characterise the tree-to-tree variation in fruit characteristics have been conducted in 300 trees from five villages (four in Cameroon and one in Nigeria) in West Africa (Waruhiu 1999). The aim of the studies was to understand the variability of 13 characteristics of the fruits from different trees so that the participatory domestication being implemented by

ICRAF and its partners is firmly based (see Leakey *et al.* 2002). In all five sites, very considerable and continuous tree-to-tree variation was found in each of the 13 measured traits, with the exception of kernel mass. The realisation that variability is greatest at the level of the individual village underlines the appropriateness of a village-based tree domestication programme for this species. Importantly, the results of the characterisation will help to identify the best individual trees for cultivar development using vegetative propagation, so taking the domestication process forward more rapidly (Leakey *et al.* 2000).

A sensory analysis was conducted to assess the effect of size on the relative intensity of organoleptic characteristics of safou fruits. Three fruit sizes (small, medium and large) were used to evaluate the level of acidity, aroma, bitterness and oiliness. Moreover undesirable characteristics such as fibrosity, sourness, saltiness, mustiness and wateriness were assessed. The results indicated that acidity and oiliness varied significantly among fruit sizes. Medium sized fruits, followed by large sized ones, had the lowest levels of undesirable characteristics (Kengni *et al.* 2001). The results of this sensory evaluation illustrate the need to add these techniques to the others being used to characterise tree-to-tree variation within the tree domestication process.

Commercialisation and processing

There is growing international interest in the commercial use of genetic resources, especially those from the tropics and consequently there are important issues (reviewed by ten Kate and Laird 1999) regarding access to these resources and the means of ensuring the sharing of benefits. Discussion of the role of tree domestication cannot, however, be divorced from that of product commercialisation, since without expanded or new markets, the incentives to domesticate are insufficient. Conversely, if the market explodes, the incentive for large-scale producers to establish monocultural plantations may sweep away the benefits that agroforestry could deliver to small-scale, resource-poor farmers around the tropics (Leakey and Izac 1996). As has been pointed out by Dewees and Scherr (1996), policies that promote the linkages between the domestication and commercialisation of non-timber forest products (NTFPs) are one of the important areas for further work. In this regard, there is also a need for better integration of the needs of the food and other industries using NTFPs with those of the subsistence farmer (Leakey 1999, Leakey and Tchoundjeu 2001).

It has been recognised that expanded markets for these products would increase the value of natural forests and benefit forest dwellers (Peters *et al.* 1989). Similarly, markets for NTFPs produced on areas already deforested could improve the income of subsistence farmers, and provide an alternative to slash-and-burn agriculture, one of the major causes of deforestation. For this to happen there is an urgent need for the domestication of trees to run in parallel with the development of post-harvest processing and the commercialisation of the products (Leakey and Izac 1996, Leakey 1999). Studies are underway to promote these activities in the rural communities, and on a small commercial scale (see Kapseu *et al.* 2002).

Integration into agroforestry

Agroforestry is increasingly providing on-farm sources of cultivated timber and non-timber forest products for domestic use and for marketing, in ways that potentially should reduce poverty and also provide some important environmental services, such as biological diversity and carbon sequestration (Leakey 2001). Consequently, filling some of the niches in farmland with indigenous species that provide economically valuable products should result in land use that is both sustainable and productive, such as the cocoa agroforests of Cameroon (Leakey and Tchoundjeu 2001). The domestication of high value agroforestry trees like safou, through genetic selection and cultivation, should increase the quality, yield and marketability of their products, so enhancing the incentive for more sustainable land-use practices.

CONCLUSION

The techniques of domesticating safou and other indigenous fruit trees and medicinal plants of the humid zone of West and Central Africa are evolving rapidly. Through the promotion of income generation they should help to reduce rural poverty and enhance the livelihoods of subsistence farmers in the region. The new emphasis placed on participatory domestication of the traditionally important, and previously ignored, indigenous fruit trees, appears to be a good strategy to help farmers to help themselves while, through the diversification of cocoa agroforests, also having benefits for the sustainable management of farmland in proximity to threatened tropical forests.

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