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TOWARDS THE DEVELOPMENT OF MIOMBO FRUIT TREES AS COMMERCIAL TREE CROPS IN SOUTHERN AFRICA

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ABSTRACT

Many rural households rely on indigenous fruit trees as sources of cash and subsistence in the Southern Africa Development Community (SADC), but until recently there has been little effort to cultivate, improve or add value to these fruits. Since 1989 the International Centre for Research in Agroforestry (ICRAF: now the World Agroforestry Centre) initiated research-and-development work on more than 20 priority indigenous fruit trees in five SADC countries aimed at improving income in rural communities. A participatory approach was used in all stages of their domestication, product development and commercialization. Country-specific priority species were identified in five countries based on discussions with a wide range of users. These species have now become the focus of a regional tree domestication programme. An impact analysis indicates that a robust domestication programme will create incentives for farmer-led investment in the cultivation of indigenous fruit trees, as an alternative to wild fruit collection, especially where there is a decrease in fruit abundance. In Zimbabwe, the returns to family labour of collecting wild fruits are two to three times greater than other farming activities. These returns will be further increased by domestication.

Progress in the domestication of four priority fruit tree species *Uapaca kirkiana*, *Strychnos cocculoides*, *Parinari curatellifolia* and *Sclerocarya birrea* from the miombo woodlands in southern Africa is reviewed. Preliminary results indicate that the long juvenile phase of *Uapaca kirkiana* can be shortened from 12-16 years to less than four years, using vegetative propagation methods.

On-going multidisciplinary tree crop domestication research includes molecular genetic analyses, tissue culture, post-harvest storage, production economics, nutritional analyses, market and supply chain surveys, processing and feasibility assessments of pilot enterprises. Holistic plans are needed to promote cultivation and ensure product quality on farms and to maximize competitiveness at the farm gate and throughout the supply chain.

Key words: Agroforestry tree products, enterprise development, livelihoods, participatory domestication, rural incomes

INTRODUCTION

In Sub-Saharan Africa indigenous fruit trees play vital roles in food and nutritional security, especially during periods of famine and food scarcity (Saka *et al.* 2002, 2004/b, Akinnifesi *et al.* 2004a), although they are becoming increasingly important as a main source of food to supplement diets in better times. The role of indigenous fruits of the miombo woodlands is particularly important in the Southern Africa Development Community (SADC) (Maghembe *et al*. 1998, Cunningham 2002, Tiisekwa *et al*. 2004), especially for the marginalized groups in society. In Zimbabwe, for example, wild fruit trees represent about 20% of total woodland resource use by rural households (Campbell *et al.* 1997) and fruits of *Uapaca kirkiana* (Muell., Arg), *Ziziphus mauritiana* (Lam), *Strychnos cocculoides* (DC ex Perleb) and *Parinari curatellifolia (*Planchon ex Benth.) are sold to buy staple food and other household goods (Ramadhani, 2002; Mithofer, 2004). Producers can obtain substantial household incomes supplying local markets (Kaaria 1998, Schomburg *et al*. 2002, Ramadhani 2002), with women and children being the main beneficiaries, although men dominate transport business and the wholesale market. In the Zambezi valley, 80% of indigenous fruit producers/collectors process fruits for home consumption (Kadzere *et al.* 2001), while in South Africa 94% of households use *S. birrea* fruits for making beer, jam and juice (Shackleton 2004), but little consideration is given to hygiene (Mumba *et al*. 2002). To redress the problem of product quality in southern Africa, ICRAF has engaged some partners in product development, business and enterprise development.

Nevertheless, these fruits do not contribute much to the regional and export trade of southern Africa, as they are not generally regarded as having commercial potential. The fruits of *Sclerocarya birrea* (Hochst.) are however used to make a liqueur (Amarula), which is traded worldwide.

Deforestation and increasing population is causing the miombo forests of southern Africa to recede, with serious consequences on the availability of wild fruits, medicinal plants and other plant products. This exposes the most vulnerable segment of the communities, the aged, the poor, women and children, to malnutrition and reduced income, as traditionally their livelihoods partly depend on forest products. The complexity and scale of the challenges facing the rural farmers in Africa are increasing, and exceed those of conventional agriculture. Until recently there has been little effort to cultivate, improve or add value to these fruits. However, since 1989 the International Centre for Research in Agroforestry (ICRAF: now the World Agroforestry Centre) has implemented a research and development initiative to domesticate and commercialise indigenous fruit trees in five SADC countries (Akinnifesi *et al*. 2004a, Maghembe *et al*. 1998). The philosophy of the ICRAF's Agroforestry Tree Domestication Programme is to build on the desire of local people to cultivate indigenous fruits and nuts and enhance the ways in which these species promote food and nutritional security, increase household income, create employment and diversify farming systems and the rural economy. The goal of domesticating these trees is to increase their quality and productivity, and to create opportunities for marketing their products, so empowering smallholder farming communities to conserve and cultivate them.

This is now seen as an important strategy to reduce poverty and hunger and to create employment opportunities in rural areas (Simons and Leakey, 2004), complementing the earlier emphasis of ICRAF on soil fertility improvement in the region (Kwesiga *et al.* 2003). The domestication of trees producing agroforestry tree products (AFTPs) will promote food and nutritional security and contribute to achieving the UN Millennium Development Goals.

In the past, miombo fruit trees have been perceived to be abundant, slow growing and inappropriate for cultivation. This perception has been aggravated by the limited understanding of the natural variability, reproductive biology, propagation and the lack of techniques for adding value and cultivation. This paper presents research activities since 1989 aimed at filling this knowledge gap for priority indigenous fruit trees.

Why domesticate indigenous fruit trees?

Farmers in southern Africa often retain and protect indigenous fruit trees. Evidence for this has been found for U*apaca kirkiana, Strychnos cocculoides* and *Parinari curatellifolia* in Malawi, Zambia, Zimbabwe, Mozambique and parts of Tanzania (Kwesiga *et al.* 2000, Akinnifesi *et al.* 2004a), and in 'marula' (*Sclerocarya birrea*) in South Africa (Shackleton 2004) and Namibia (Leakey, 2005).

Local plantings, product development and market expansion are the first steps in domesticating wild fruit trees in their fields, homesteads and communal lands (Maghembe *et al.* 1998, Leakey *et al.* 2004), adapting them to their needs and environmental conditions by deliberately or inadvertently selecting for certain characteristics. Domestication involves accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven and market-led process (ICRAF 1997). Only about 50 fruit trees have been either domesticated or semi-domesticated (Leakey and Tomich 1999), but in Tanzania alone over 300 indigenous plants have been described as edible (Ruffo *et al.* 2002), but few, if any, of these species have been domesticated through deliberate tree improvement programmes.

The current ICRAF Tree domestication initiatives are focused on *Sclerocarya birrea, Uapaca kirkiana*, *Strychnos cocculoides, Vangueria infausta, Parinari curatellifolia, Ziziphus mauritiana, Adansonia digitata, Syzigium cordatum* (Gaertner) and *Vitex species* (Maghembe *et al.* 1995, 1998, Mateke 2000, 2003, Kwesiga 2000; Akinnifesi *et al.* 2004a, b). The southern Africa regional programme is also part of a global strategy developed by ICRAF and its partners in which tree domestication is seen as a farmer-led and market-driven process, which utilizes the intraspecific diversity of locally important trees to meet the needs of subsistence farmers, product markets, and agricultural environments.

DEVELOPING AND IMPLEMENTING A TREE CROP DEVELOPMENT STRATEGY

Tree crop development and commercialization of fruit trees from the miombo woodlands in southern Africa requires a long-term, iterative and integrated strategy for tree selection and improvement, for the promotion, use and marketing of selected germplasm and its integration into agroforestry practices (Akinnifesi *et al.* 2004a). The key components are:

- verification of the importance and potential of indigenous fruits in the rural economy,
- initiation of a Tree Domestication Programme to select and improve germplasm, promotion of the indigenous fruit production with the new cultivars, and
- commercialisation of the new products through a functional supply chain (fruit storage and processing, product quality assurance, adding value, marketing, rural revenue generation and enterprise development) (Figure 1).

Among many approaches to tree improvement the miombo domestication programme has considered and used both forestry- and horticulture-based approaches. The 'horticultural' approach captures superior genetic variants

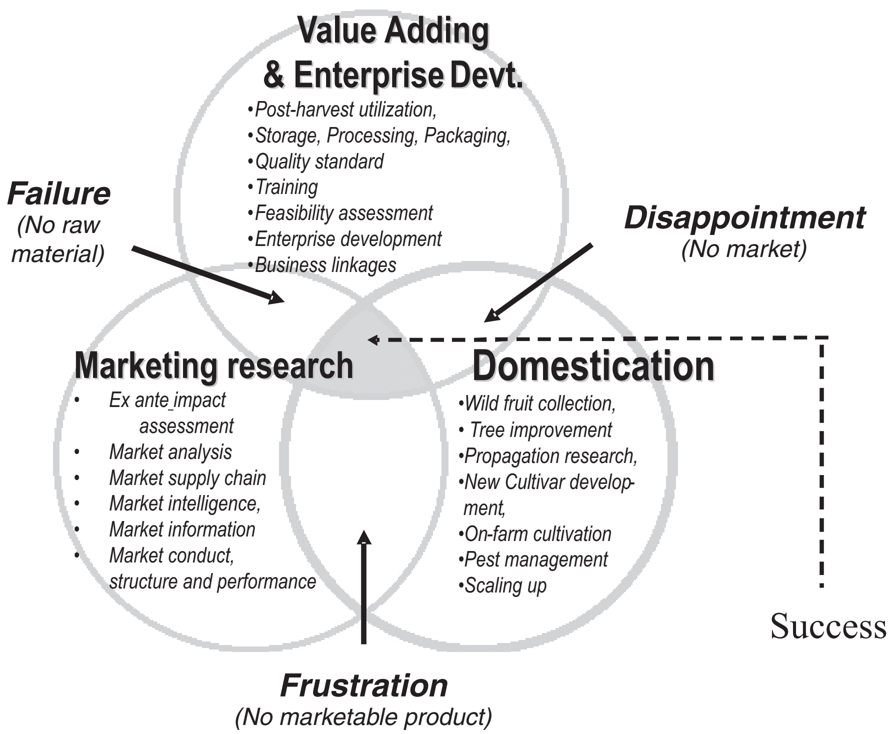

Figure 1. Key components of indigenous fruit tree crop developments in southern Africa.

through vegetative (asexual) propagation. In this approach no further segregation or recombination of genes is required to maintain the desirable genotype as a cultivar. This approach can be used to achieve rapid genetic gain, but needs to be integrated with tree breeding to ensure long term genetic improvement. In contrast, the 'forestry' approach is based on sexual propagation and the selection of breeding populations and progenies. The conventional forestry approach to tree improvement typically retains greater pools of genetic diversity in the breeding population and allows for improvement over the long term (Nyland 1996). However, in long-lived perennial species this approach can be more time consuming and expensive than clonal methods. The forestry approach involves sequential steps such as species elimination trials, species selection, provenance and progeny trials, to identify the best mother trees within a seed source, and then collection of the best germplasm from mother trees to establish clonal seed orchards, and production of high quality seeds or seedlings from orchards for dissemination to growers.

Improving the quality and uniformity of the fruits through domestication and cultivation can help in achieving the market expansion needed to generate increased cash income beyond the current opportunistic marketing of wild fruits. This is a long-term investment that may require years to translate into profits for smallholder farmers, traders and entrepreneurs. The development of improved cultivars, using vegetative propagation of already proven superior phenotypes, is the strategy which will achieve most rapidly the objective of generating increased farm income from indigenous miombo fruits.

The following steps have been taken to develop and initiate the implementation of this strategy in the SADC Region:

Impact analysis

Previous studies show that indigenous fruits contribute on average about 42% of the natural food basket that rural households rely on in southern Africa (Campbell *et al. 1*997). Several studies were conducted to understand the importance of contribution of miombo fruits to the livelihoods of the rural communities in the region. An impact analysis of the whole farm in Zimbabwe showed that all families consume indigenous fruits. The home consumption and marketing of these fruits contributed substantially to household livelihoods and cash income, and enabled households to live above the poverty line during the critical famine periods. Indigenous fruits contributed to a poverty reduction of up to 30% and an income above the poverty line throughout the year (Mithofer 2004, Ramadhani 2002). In 2002, a household food security survey found that about 60–85% of rural households in the "Chinyanja Triangle" (i.e. Malawi, Zambia and Mozambique), lacked access to food for three to four months per year, and 26–50% of the respondents had relied on indigenous fruits for sustenance during this critical period (Akinnifesi *et al.* 2004a). In a global analysis of the marketing and cultivation of wild forest products Ruiz-Perez *et al*. (2004)

found that farmers engaged in the cultivation of indigenous fruits had higher returns to labour, used more intensive production technologies, produced more tree products per hectare and benefited from a more stable resource base, than those relying on wild collection. In South Africa, Shackleton (2004) reported that 30% of households have planted *S. birrea* in their homesteads (25% used truncheons, 31% transplanted wildings and 44% planted seeds directly). The various studies above, suggest that the cultivation of wild fruit trees will become more important as rural households move from subsistence to a cash-oriented economy and support the general notion that enhanced demand for the fruits contributes to on-farm management of the respective trees (Arnold & Dewees 1999). Domestication activities are essential if tangible commercial interest in indigenous fruits is to emerge beyond the current opportunistic levels at roadside and local markets. Domestication and commercialization of AFTPs must take place in parallel (Wynberg *et al.* 2003).

A simulation model of year-round income flows of households' enterprises using indigenous fruits to diversify their income suggests that the benefits from selling indigenous fruits come at a critical time when income is generally low, and provides nutrition and food when agricultural labour demands are high (Mithofer 2004). Furthermore, in Zimbabwe, financial returns from collecting indigenous fruits were 2–4 times greater than the returns from regular farming activities in communities located near forests. Despite the availability of wild fruits, improvements in tree yield and earlier fruiting would be incentives to cultivate indigenous fruits (Mithofer and Waibel 2003). In Malawi, wild fruits are most important in the areas where rural people frequently face annual food shortages and the deforestation rate is high. In these areas, 70% of farmers were willing to pay for seedlings and to plant indigenous fruit trees (German 2003).

Choice of species to domesticate

A region-wide priority setting survey to determine farmers' preferences and match these with existing scientific knowledge and market potential was conducted using Participatory Rural Appraisal techniques (Franzel *et al.* 1996). This involved household and market surveys conducted in Malawi, Tanzania, Zambia and Zimbabwe across a total of 451 households from 20 districts (Maghembe *et al.* 1998). These surveys also recorded local knowledge on fruit processing (Maghembe *et al.* 1998).

Four priority species for the Regional Tree Domestication Programme of ICRAF and partners were identified as *Uapaca kirkiana, Strychnos cocculoides, Parinari curatellifolia* and *Sclerocarya birrea* (Table 1). Of these species, *U. kirkiana* is the top priority for intensive research. However, at the national level, other species were recognized as top priority (*Vitex mombassae* for Tanzania, *Trichilia emetica* [P. Browne.] and *Adansonia digitata* for Mozambique, *Anisophyllea boehmii* for Zambia, *Flacourtia indica* and *Azanza garkeana* for Malawi, *A. garkeana* and *Vitex payos* for Zimbabwe). *S. birrea* is important in South Africa where it has been widely used by rural households, especially at the Bushbuckridge region, where Shackleton (2004) estimated that up to 78% of household had this species in their homesteads which was mainly the result of commercialization in the processing of wine and other products. Other species were also identified as being important at the national level (see Table 1) especially for the on-farm management of genetic biodiversity.

The household surveys also identified the important traits for improvement. Thus the following species specific traits for improvement were identified: *Uapaca kirkiana, Parinari curatellifolia* and *Sclerocarya birrea* (reduced juvenile phase). *Azanza garckeana* (reduced fibre content), *Flacourtia indica*, *P. curatellifolia*, *U. kirkiana* and *Ficus sycomorus* (longer shelf life), *P. curatellifolia* and *U. kirkiana* (pest and disease resistance).

Participatory approach

Participatory approaches to the domestication of indigenous fruit trees have been developed in southern Africa (Figure 2) recognizing that:

- farmers have good knowledge of the natural variability in fruit and kernel traits and that they can locate and identify superior trees,
- user groups differ in their criteria for choosing superior phenotypes,
- the collection of qualitative and quantitative information assists the identification of the best trees, and
- the importance of training community farmers in nursery management and simple domestication techniques.

TABLE 1

Differential emphasis of regional and national priority indigenous fruit trees using spearhead and shield approach (1 = very high, 2 = high, 3 = medium, 4 = low).

Species	Region	Malawi	Zambia	Zimbabwe	Tanzania	Mozambique
Uapaca kirkiana	1	1	1	1	3	1
Strychnos cocculoides	1	1	1	1	1	1
Parinari curatellifolia	2	1	1	2	3	1
Sclerocarya birrea	2	3	2	1	1	2
Ziziphus mauritiana	2	4	2	1	1	2
Adansonia digitata	2	2	2	2	1	2
Tamarindus indica	4	4	4	1	3	4
Flacourtia indica	4	4	2	4	4	4
Anisophyllea boemii	4	2	4	4	4	4
Syzigium guineense	4	2	4	4	4	4
Azanza garckeana	2	4	1	4	4	4
Vitex mombassae	4	4	4	1	4	4

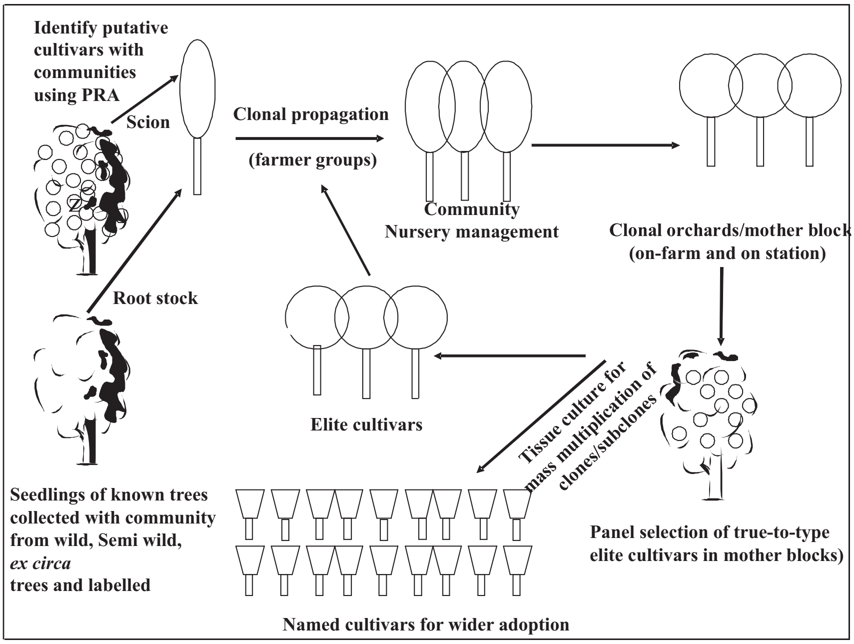

Figure 2. Selecting putative cultivars of indigenous fruit trees from the wild in Southern Africa.

In southern Africa, trees are often known by individual names, called after members of the community or some important characteristic. The existence of these names illustrates the extent and value of indigenous knowledge. One of the purposes of promoting participatory domestication is to build on this knowledge in ways, which ensure that the benefits flowing from the development of cultivars remain with the community (Leakey *et al*. 2003).

At the start of this programme, participatory rural appraisal techniques were used in small groups to determine the selection criteria. Then superior trees of the four priority species were tagged according to year of collection, location and ownership. Site descriptors were documented and fruits sampled for detailed assessment of the qualitative and quantitative characteristics, including chemical and organoleptic analysis. Seeds and scions were also collected for growth and multiplication in the nursery, and subsequent establishment of fruit orchards. In some cases, duplicate materials were collected by farmers and raised in individual or group nurseries in their own communities.

DOMESTICATION PROCESS FOR INDIGENOUS FRUIT TREES

Fruit characterization

Measurements of tree-to-tree variation in indigenous fruits (size, sugar and pulp content) have been made and have identified great variation in wild populations (e.g., *S. birrea* - Thiong'o *et al.* 2002, Leakey *et al.* 2005 a/b), and *U. kirkiana* (Akinnifesi *et al*. 2004; Kadzere *et al.* 2005). The variability of fruit characteristics was clear – as illustrated in the ideograph of *Uapaca kirkiana* (Figure 3). Tree 40 at Mafa had the highest pulp content, largest fruit weight, but low sugar content (% brix), while Tree 29 at Uranda had very sweet, small fruits and high pulp content. Tree 9 at Chimani, on the other hand, despite having large fruits, was rejected as it had low pulp content, high shell weight and low sugar content. However, it is important to recognize that some fruit traits, including tree fruit load and pulp content per fruit, can be manipulated to a limited extent by management practices such as thinning (Mwamba 1995).

Having identified some superior trees of the priority species, the next stage is to propagate these trees and introduce them into the farming system. This requires knowledge about plant selection and improvement, nursery production, establishment of tree crops, post-harvest handling, grading and transport and product marketing. All of these components are important to introduce a new plant product to the market successfully; ignoring just one will considerably reduce the probability of commercial success.

Elite tree selection

Typically, through the characterization, selection and propagation of elite genotypes, the domestication process leads to the creation of cultivars with higher quality products and improved uniformity that make the products more

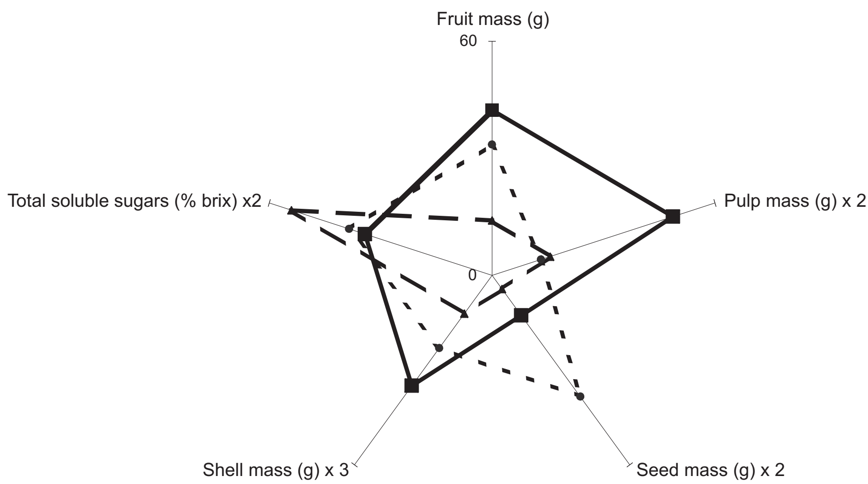

Figure 3. Phenotypic variation in farmer selected elite trees of *Uapaca kirkiana* trees in Zimbabwe (Tree 29 Uranda = ── ──; Tree 9 Chimani = ----- and Tree 40 Mafa = ───)

attractive to consumers and processors. In southern Africa, a consensus has been reached among stakeholders as to what traits should be improved (Maghembe *et al.* 1998). The most important of these included:

- a reduced time to first fruiting, and
- selection for large, sweet fruits with a high pulp content.

Leakey and Page (2006) describe ways of combining such useful traits into the ideal tree – or 'ideotype.'

Although time to first fruiting can be a genetic trait, it can also be manipulated by vegetatively propagating fruit trees from mature tissues, so eliminating the juvenile phase. They will also be smaller in stature and because of their smaller crown produce fewer fruits, but they can be grown at higher numbers per unit area to compensate for this.

An orchard of *U. kirkiana* was established in Makoka, Malawi from selected sexually mature wild individual trees using marcots and grafts on rootstocks from seedlings raised from fruits collected from the same trees. The mature clonal plants in the orchard started to flower and fruit two years after establishment in the field (Akinnifesi *et al.* 2004a), although, so far – except in the third year, fruit retention to maturity has been very low. In contrast none of the seedling-derived trees have flowered. This result is promising considering that the juvenile period in seedling populations of *U. kirkiana* is typically 10 to 12 years. Such clonal orchards are starting to contribute to the tree improvement component of the domestication programme.

Nursery production

Germination and seed storage

Lack of planting materials has been frequently cited by farmers as the major constraint to growing indigenous miombo fruit trees (Akinnifesi *et al.* 2004a). Considerable progress has been made in developing germination protocols (Maghembe and Msanga 1989, Maghembe 1995, Mkonda *et al.* 2003). A few species have been found to germinate well without special treatments (*Ximenia caffra*, *Tamarindus. indica, Parkia filicoides*, *Ziziphus spp., Bridelia cathartica, Diospyros mespiliformis* and *A. digitata*), while others require scarification (*Azanza gackeana, Uapaca indica*), or soaking in water (*Adansonia digitata, Syzygium cordatum, Vitex doniana, Sclerocarya birrea*) (Mwabumba and Sitaubi 1995, Mateke 2000). However, a number of species have proved to be difficult to germinate from fresh seed, despite a range of treatments (*Strychnos cocculoides, Parinari curatellifollia, Vangueria infausta* (Maghembe, 1995). This problem has recently been overcome for *S. cocculoides* by prolonged periods (e.g. 2 years) of seed storage under room conditions (Mateke 2000, 2003, Mkonda *et al.* 2003). Some evidence (Mateke 2003) also suggests that the date of sowing affects the gemination rate of *S. birrea* (August – 87% and June – 24%), *Azanza gackeana* (July – 37% September – 85%) and *Vangueria infausta* (June – 56% November – 98%), however, this may also reflect temperature differences or the time spent in storage. In Makoka, 100% germination has been obtained in *U. kirkiana* by soaking freshly collected seeds in water overnight under room conditions.

Vegetative propagation

Until recently, poor success with vegetative propagation has been a constraint to domestication of indigenous fruit trees in southern Africa, for example <10% grafting success was earlier reported for *U. kirkiana* (Jaenicke *et al.* 2001). However, these problems have been overcome with improved grafting and scion collection conditions (*A. digitata* 85–100%, *Mangifera indica* 97%, *U. kirkiana* 80%, *Strychnos cocculoides* 40–79%, *Sclerocarya birrea* 52–80%, *Vangueria infausta*, 100%, *P. curatellifolia* 71%) (Mhango and Akinnifesi 2001). Some factors determining grafting success are: the skill of the person grafting, the time of the year scion is collected and the interval between scion collection and grafting (Akinnifesi *et al.* 2004a). Other factors may include proper alignment of the vascular tissues between scion and rootstock, stock plant nutrition, scion respiration rates, disease condition of scion and rootstock, and relative humidity of propagation environment. Air layering has also been found to be feasible for many of the indigenous fruit tree species, especially for *U. kirkiana* (63%). The best time to set *U. kirkiana* marcots is during August to October, and no root-initiation hormone is required. However, the survival of established marcots is still a challenge in some cases.

Seasonality and annual variation in fruit yield

In addition to their fruit morphology, trees vary in their seasonality (Ngulube *et al.* 1995). Typically, this variation is normal phenotypic variation, and offers opportunities for selection and the development of early- and/or late-fruiting varieties, which can extend the fruiting season and potentially increase the amount of the annual harvest. When this variation is observed between populations from different geographic origins it can be the result of phenotypic adaptation to climatic variables or day length differences between different latitudes.

Tree fruit yields are commonly subject to much year-to-year variation, being strongly influenced by the environment. Nevertheless, in southern Africa, some trees seem to produce fruits annually, in alternate years or, occasionally, some trees fruit biannually (Maghembe, 1995) suggesting that it may be possible to have two fruiting seasons. Year-to-year climate fluctuations make it important to evaluate these characteristics in replicated trials over several years and in different locations. In Botswana, for example, yields of a number of miombo fruit trees have been observed over three years. The yield of one mature *S. birrea* tree at Tsetsejwe was estimated at over 18,000 fruits in 1998/99, but it had produced no fruit the previous year. This was nearly twice that of the 3-year mean (just under 10,000 fruits) for seven superior *S. birrea* trees in the wild (Mateke, 2003). The fruit load of *U. kirkiana* was observed to be very different at different locations within and between countries (I. Kadzere, unpublished data).

Evidence is accumulating that the fruit yields from trees near homesteads and in managed fields are greater than those from wild trees. For example, in South Africa, *S. birrea* trees in farmers' fields produced more and heavier fruits (>17,000 fruits per tree) than wild ones in natural woodlands (<3500 per tree) (Shackleton 2004).

Multi-location provenance trial

Under the 'forestry' approach to tree improvement, seeds were collected from superior wild trees of 26 selected provenances of *U. kirkiana* (5–6 provenances from each of Malawi, Tanzania, Zambia, Mozambique and Zimbabwe) and *S. birrea* (2–6 provenances from each of Malawi, Tanzania, Zambia, Mozambique, Zimbabwe, Mali, Namibia and Kenya) and exchanged among countries and established in multi-location trials with 12–16 provenances per country (Kwesiga *et al*. 2000, Akinnifesi *et al*. 2004b). Two collection strategies were used for all four target species: (i) targeted collections (500 fruits from each of 25 farmer-selected trees) from homesteads and farmlands (semi-domesticated), and (ii) a collection (500 fruits from each of 25 trees per population located 100m or more apart along a transect line) from trees in the forest. The objective of the trials was to understand the adaptability and performance of germplasm collected across diverse climatic and geographic zones and identify promising provenances that could serve as seed sources for progeny that will perform under various agro-climatic conditions.

An early assessment after only 42 months indicated that the best performing provenances for *U. kirkiana* were: Phalombe for Malawi, Murelwa for Zimbabwe and Chipata for Zambia. Tree height was strongly correlated with geographic and climatic variables and with significant Genotype x Environment interactions in height growth across the three countries (for more detail see Akinnifesi *et al.* 2004b). These *U. kirkiana* trees have not yet flowered generally, but a few individuals from a single mother tree from each of Mapanzure and Serenje provenances from Zimbabwe and Zambia respectively, fruited in Makoka, Malawi for the first time after 8 years. *S. birrea* trees from the provenance Marracuene, Mozambique also started fruiting after 4–5 years at Mangochi, Malawi. These precocious superior individual provenances will be used as future seed sources, as well as a source of scions for clonal propagation in order to meet consumer demand.

Molecular studies of genetic diversity

Molecular studies using random amplified polymorphic DNA (RAPD) analysis of 16 populations of *S. birrea* (80 RAPDs) and 17 populations of *U. kirkiana* (132 RAPDs), have been undertaken to elucidate the extent and distribution of genetic variation within and between tree populations (Agufa 2002). The results indicate high, geographically structured variability with 75% within-provenance variation. This provides a guide to the wise use, management and conservation of germplasm, and emphasizes the importance of collecting extensively within-provenance, as well as range-wide in order to capture the whole of the genetic diversity of the species. A study of chloroplast DNA indicated that Tanzania is a centre of diversity for *S. birrea*, with three subspecies (var. *birrea, caffra, multifoliata*). Analysis of molecular variance indicates that variation between populations was greater for *S. birrea*, than for *U. kirkiana.* Cluster analysis of genetic distances for both species, suggests that the patterns of variation in both species is complex (Agufa 2002).

FARMER TRAINING

The participatory surveys of communities throughout the region have involved farmer training in the concepts and techniques of tree domestication, with nearly 13,000 farmers being trained in tree propagation, nursery establishment and management, and farm management. Indigenous fruit tree seedlings have been disseminated to farmers in four countries (Malawi, Zambia, Zimbabwe and Tanzania) since the late 1990's. A survey in Malawi and Zambia indicated that homesteads were the main planting sites for the trees (86% households in Malawi and 98% in Zambia), but drought has affected survival of *Strychnos cocculoides* and *Sclerocarya birrea.*

Farmer-to-farmer exchange and farmer training have been important methods of training larger number of farmers in nursery establishment and tree management. Special emphasis has been given in each community to train a few people in grafting techniques, as this is central to the domestication programme. These trainees can then offer services to other farmers and farmer groups, as well as manage their own commercial nurseries.

LAND AND TREE TENURE AND INSTITUTIONAL ARRANGEMENTS

One of the constraints of tree domestication and commercialization in the region are the systems of land and tree tenure. Studies in Zimbabwe have shown that written formal and unwritten informal policies govern the use of the trees and fruits in Zimbabwe (Ramadhani 2002). Under Government policy in Zimbabwe indigenous fruit trees are treated as a public good, because they were regarded as having no commercial value in the colonial era. Settlers have limited access to indigenous fruits and other forest products. Even farmers with commercial land, owning their farms have to notify the Forestry Commission before an indigenous tree can be cut.

Indigenous fruits on communal lands are treated as open access goods available to anyone. Communal land and tree tenure is the largest tenure system in Zimbabwe (75% of the rural population and covering 43% of the woodlands) and most community leaders are aware of the regulations guiding harvesting and marketing of fruits but, most are unaware of any laws on planting indigenous fruit trees.

A recent study in Malawi and Eastern Zambia showed that a customary land tenure system is dominant (German 2003). In communal lands, trees are common property and fruits can be harvested without management. The free access to fruits in both State and communally owned land is a disincentive to planting indigenous fruit trees. The land inheritance system also affects peoples' willingness to plant trees. In matrilineal households, husbands are hesitant to plant any type of trees, because ownership of trees reverts to their wives, if divorce or separation occurs. Patrilineal communities are more conducive for fruit tree cultivation.

HARVESTING AND POST-HARVEST HANDLING

Common property resources tend to be subject to over-harvesting and poor stewardship. Despite traditional regulations, byelaws and superstitious beliefs aimed at conserving these commonly owned wild resources, inappropriate methods are used to harvest indigenous fruits in southern Africa – often causing considerable tree damage (Kadzere *et al*. 2001, Ramadhani 2002). The use of stock of shorter stature from the vegetative propagation of mature trees may reduce this type of damage. Also, often, the condition of the fruit at the time of sale in the markets is poor. A number of approaches to raise the quality have been suggested, including:

- developing harvesting methods that minimizes fruit loss and increases the yield per tree,
- acquiring a better understanding of fruit ripening patterns so that post-harvest ripening can be successfully applied to miombo fruits (Kadzere *et al*. 2001), and
- improving transport of the fruit to market with protection from the sun and less handling (Kaaria 1998, Ramadhani 2002, Saka *et al.* 2004). Appropriate packaging should to be durable, re-usable, ergonomically effective, affordable and cost effective.

MARKETS AND VALUE ADDING

In addition to domestic consumption, miombo fruits are traded locally, regionally and sometimes internationally. The main products made from indigenous fruits are alcoholic and non-alcoholic beverages, confectionaries, additives for other foods, dried whole fruits, oil and kernel butter (Kadzere *et al*. 2001). Opportunities for value adding with marula (*S. birrea*) fruits and nuts have been explored in almost every country in region, including traditional beers and wines, 'Amarula' liqueur in South Africa, fruit juices, jam, kernel oil for cosmetics and flavourings for biscuits and chocolate. At one time "Mulunguzi wine" was commercialized from *U. kirkiana* in Malawi (Ngwira, 1996), while currently, wine of export quality is produced from *Ziziphus mauritiana* in Lusaka Zambia (Namkolo Mukutu, personal communications). A recent analysis of markets in southern Africa, revealed that indigenous fruit markets are largely informal, small, and volatile. In addition, the season is short and the products are bulky and perishable. Other market constraints include seasonal gluts, limited and conflicting market knowledge, lack of marketing networks and associations, inadequate policies and inadequate processing and storage methods (Russell and Franzel 2004).

To date, at least 4,000 of rural women have been directly trained in processing of indigenous fruits into juices, jams and wine in Malawi, Tanzania, Zambia, and Zimbabwe (Table 2). In Tabora, Tanzania, nearly 200 rural women were trained in four groups, and after 18 months these women had in turn trained another 2,000 processors in 19 villages (Saka *et al*. 2004).

A feasibility study in Malawi, Zambia, Tanzania and Zimbabwe has indicated that rural processors could produce a diverse range of fruit concentrates throughout the year, and that these would be cheaper for entrepreneurs than importing concentrates from South Africa (Mander, M, Jordan, D., Ham, C. and F.K. Akinnifesi, unpublished). Business plans for rural agroforestry enterprises that link grassroots micro-entrepreneurs with private business and/or micro-finance sources, need to be developed in order to increase the opportunity for African products to penetrate the export market.

CONCLUSIONS

Many miombo indigenous fruit trees are important for food and nutritional security, as well as being a source of income. The evidence that indigenous

TABLE 2

The range of products being processed by rural women training in value-adding processing

Malawi and Zambia	Baobab juice, jam and wine (*A. digitata*), Masuku juice, jam (*U. kirkiana*), Marula wine (*S. birrea*). Wines are also made from several non-indigenous products
Zimbabwe	*Parinari* oil (*P. curatellifolia*), Strychnos jelly (*S. cocculoides*), Masuku jam (*U. kirkiana*), Marula oil and jelly (*S. birrea*), Masau leather (*Z. mauritiana*), Baobab oil and cereal bar (*A. digitata*).
Tanzania	Baobab juice (*A. digitata*), Syzygium juice (*S. guineense*), Strychnos juice (*S. cocculoides*), Vitex jam (*V. mombassae*).

fruits and products provide avenues for small-holder farmers to improve their livelihoods in southern Africa is striking. A programme to domesticate these species has been in progress for nearly one decade and has made considerable progress in identifying opportunities, formulating and implementing domestication strategies and examining the economic and social environment as well as the aspirations and interest of smallholder farmers who are the target beneficiaries. Several thousand farmers and community members have been trained in tree selection, propagation and nursery management, planting and cultivation, and processing indigenous fruits for home consumption and markets. The marketing and commercialization component of this programme is currently receiving more emphasis. Rural entrepreneurs have been trained in fruit processing and business skills. The dissemination of these innovations have involved farmer-to-farmer exchanges where successful farmers pass on their skills and experience to new farmers entering the business, as well as formal courses to train trainers. This bottom-up approach has ensured community ownership of the implementation of the business and dissemination skills, and a market driven tree domestication initiative and promises to have a significant effect in raising rural incomes.

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REFERENCES

Agufa C.A.C. 2002. Genetic variation in *Sclerocarya birrea* and *Uapaca kirkiana* – Indigenous fruit trees of the miombo woodlands. MSc Thesis, Jomo Kenyatta University of Agriculture and Technology, Kenya, 123 pp.

Arnold J.E.M. and Dewees P.A. 1999. Trees in managed landscapes: factors in farmer decision making. Pp. 277–294 in Buck L.E., Lassoie J.P. and Fernandes E.C.M. (eds.). *Agroforestry in Sustainable Agricultural Systems*. Lewis Publishers. Boca Raton, Florida.

Akinnifesi F.K., Kwesiga F.R., Mhango J., Mkonda A., Chilanga T. and Swai R. 2004a. Domesticating priority miombo indigenous fruit trees as a promising livelihood option for smallholder farmers in southern Africa. *Acta Horticulturae* **632**: 15–30.

Akinnifesi F.K., Chilanga T., Mkonda A. and Kwesiga F. 2004b. Domestication of *Uapaca kirkiana* in southern Africa: A preliminary evaluation of provenances in Malawi and Zambia. Pp. 85–92 in Rao M.R. and Kwesiga F.R. (eds.) *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihooods in Southern Africa: Putting Research into Practice*: World Agroforestry Centre: Nairobi, Kenya.

Campbell B., Luckert M., Scoones I. 1997. Local level valuation of Savannah resources: A case study from Zimbabwe. *Economic Botany* **51**: 57–77.

Cunningham A.B. 2002. *Applied Ethnobotany: People, Wild Plant Use and Conservation Manuals*. WWF and Earthscan Publications Ltd, London and Sterling, VA. 300 pp.

Franzel S., Jaenicke H. and Janssen W. 1996. Choosing the right trees: setting priorities for multipurpose tree improvement, The Hague: International Service for National Agricultural Research, *Research Report* **8**: 87p.

German G.M. 2003. Land tenure, land-related factors and tree tenure systems: An investigation of farmer willingness to cultivate miombo fruit trees in Malawi and Eastern Zambia. MSc Thesis, Bunda College, University of Malawi. 115 pp.

ICRAF 1997. *Annual Report 1996*, ICRAF, Nairobi, Kenya.

Jaenicke H., Simons A.J., Maghembe J.A., Weber J.C. 2001. Domesticating Indigenous Fruit Trees for Agroforestry. *Acta Horticulturae* **523**: 45–51.

Kaaria S.W. 1998. The economic potential of wild fruit trees in Malawi. Thesis, Faculty of the Graduate School of the University of Minnesota: 173 pp.

Kadzere I., Hove L., Gatsi T., Masarirambi M.T., Tapfumaneyi L., Maforimbo E., Magumise I., Sadi J. and Makaya P.R. 2001. Current Practices on Post-harvest handling and traditional processing of indigenous fruits in Zimbabwe. *Final Technical Report to Department of Agricultural Research and Technical Services*, Zimbabwe, 66pp.

Kwesiga F., Akinnifesi F.K., Ramadhani T., Kadzere I. and Saka J. 2000. Domestication of Indigenous fruit trees of the miombo in southern Africa. Pp. 8–24 in Shumba, E.M., Lusepani, E. and Hangula, R. (eds). *The Domestication and Commercialization of Indigenous Fruit Trees in the SADC Region*. SADC Tree Seed Centre Network.

Kwesiga F., Akinnifesi F.K., Mafongoya P.L., McDermontt M.H. and Agumya A. 2003. Agroforestry research and development in southern Africa during the 1990s: Review and challenges ahead. *Agroforestry Systems* **59**: 173–186.

Leakey R.R.B. 2005. Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 3. Multi-trait selection. *Agroforestry Systems* **64**: 51–59.

Leakey R.R.B. and Page, T. 2006. The 'ideotype concept' and its application to the selection of 'AFTP' cultivars. *Forests, Trees and Livelihoods* **16**: 5–6.

Leakey R.R.B. and Tomich T.P. 1999. Domestication of tropical trees; from biology to economics and policy. Pp. 319–338 in L.E. Buck, J. Lassoie and E.C.M. Fernandes (eds.), *Agroforestry in Sustainable Agriculture Systems*, CRC Press/Lewis Publishers, New York.

Leakey R.R.B., Schreckenberg K. and Tchoundjeu Z. 2003. The participatory domestication of West African indigenous fruits. *International Forestry Review* **5**: 338–347.

Leakey R.R.B., Tchoundjeu Z, Smith R.I., Munro RC., Fondoun J-M., Kengue J., Anegbeh P.O., Atangana A.R., Waruhiu A.N., Asaah E., Usoro C. and Ukafor V. 2004. Evidence that subsistence farmers have domesticated indigenous fruits (*Dacryodes edulis and Irvingia gabonensis*) in Cameroon and Nigeria. *Agroforestry Systems* **60**: 101–111.

Leakey R.R.B., Shackleton S. and du Plessis P. 2005. Domestication potential of Marula (*Sclerocarya birrea subsp caffra*) in South Africa and Namibia: 1. Phenotypic variation in fruit traits, *Agroforestry Systems* **64**: 25–35.

Leakey R.R.B., Pate K. and Lombard C. 2005. Domestication potential of Marula (*Sclerocarya birrea subsp caffra*) in South Africa and Namibia: 2. Phenotypic variation in nut and kernel traits. *Agroforestry Systems* **64**: 37–49.

Maghembe J.A. 1995. Achievement in the establishment of indigenous fruit trees of the miombo woodlands of southern Africa. Pp. 39–49 in J.A. Maghembe, Y. Ntupanyama and P.W. Chirwa (eds.) *Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa*. ICRAF, Nairobi, Kenya.Maghembe J.A. and Msanga H.P. 1989. Effect of physical scarification and treatment of germination of *Trichilia emetica. International Tree Crops Journal* **5**: 163–177.

Maghembe, J.A., Simons, A.J., Kwesiga, F. and Rarieya, M. 1998. *Selecting Indigenous Trees for Domestication in Southern Africa: Priority Setting with Farmers in Malawi, Tanzania, Zambia and Zimbabwe*. ICRAF, Nairobi, Kenya. 94 pp.

Mateke S. 2000. Tree improvement in the domestication programme of indigenous fruit trees native to southern Africa: The Botswana experience. Pp. 29–35 in Shumba, E.M., Lusepani, E. and Hangula, R. (eds). *The Domestication and Commercialization of Indigenous Fruit Trees in the SADC Region*. SADC Tree Seed Centre Network, Gaborone, Botswana.

Mateke S. 2003. *Cultivation of Native Fruit Trees of Kalahari Sandveld: Studies on the Commercial Potential, Interactions between Soil and Biota in Kalahari Sands of Southern Africa*, Veld Products, Botswana. Pp. 49.

Mhango J. and Akinnifesi F.K. 2001. On-farm assessment, farmer management and perception of priority indigenous fruit trees in southern Malawi. Pp. 157–164 in Kwesiga F., Ayuk E. and Agumya A. (eds.), *Proceedings of 14th Southern African Regional Review and Planning Workshop*, 3–7 September 2001, Harare, Zimbabwe: International Centre for Research in Agroforestry.

Mithöfer D. 2004. Economics of Indigenous Fruit Tree Crops in Zimbabwe. PhD Thesis, Department of Economics and Business Administration, University of Hannover. Hannover, Germany.

Mithöfer D. and Waibel H. 2003. Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. *Agroforestry Systems* **59**: 295–305.

Mkonda A., Lungu S., Maghembe J.A. and Mafongoya P.L. 2003. Fruit- and seed germination characteristics of *Strychnos cocculoides* an indigenous fruit tree from natural populations in Zambia. *Agroforestry Systems* **58**: 25–31.

Mumba M.S., Simon S.M., Swai R. and Ramadhani T. 2002. Utilization of indigenous fruits of miombo woodlands: A Case of Tabora District, Tanzania. Pp. 35-38 in Rao M.R. and Kwesiga F.R. (eds.) *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research into Practice*. World Agroforestry Centre: Nairobi, Kenya.

Mwabumba L. and L. Sitaubi 1995. Seed pre-treatment, growth and phenology of some indigenous fruit trees of the miombo ecozone at Naugu Forestry Reserve, Malawi. Pp. 66-72 in Maghembe J.A., Ntupanyama Y. and Chirwa P. W. (eds.). *Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa*, ICRAF, Nairobi, Kenya.

Mwamba C.K. 1995. Variations in fruits of *Uapaca kirkiana* and the effects of in *situ* silvicultural treatments on fruit parameters. Pp 27-38 Maghembe J.A., Ntupanyama Y. and Chirwa P. W. (eds.). *Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa*, ICRAF, Nairobi, Kenya.

Ngulube M.R., Hall J.B. and Maghembe J.A. 1995. Ecology of miombo fruit tree: Uapaca kirkiana (Euphorbiaceae). *Forest Ecology and Management* **77**: 107–117.

Ngwira T.N., 1996. Utilisation of local fruit in wine making in Malawi. Pp. 188–191 in Leakey R.R.B, Temu A.B., Melnyk M. and Vantomme P. (eds.), *Domestication and Commercialisation of Non-timber Forest Products in Agroforestry Systems*, FAO Non-wood Forest Products 9, Rome, Italy.

Nyland R. 1996. *Silviculture: Concepts and Applications*. McGraw-Hills Companies, Inc., U.S.A., 633 pp.

Ramadhani T. 2002. Marketing of indigenous fruits in Zimbabwe. *Socio-economic Studies on Rural Development*, Vol 129. Wissenschaftsverlag Vauk. Kiel, Germany.

Ruffo C.K., A. Birnie and B. Tengnas 2002. *Edible plants of Tanzania*. RELMA Technical Handbook Series 27. Nairobi, Kenya: Regional Land Management Unit, Swedish International Development Cooperation Agency (Sida), 766 p.

Ruiz-Perez M., Belcher B., Achdiawan R., Alexiades M., Aubertin C., Caballero J., Campbell B., Clement C., Cunningham T., Martinez A., Jong W. de, Kusters K., Kutty M.G., Lopez C., Fu M., Alfaro M.A., Nair T.K., Ndoye O., Ocampo R., Rai N., Ricker M., Schreckenberg K., Shakleton S., Shanley P., Sun T. and Young Y-C. 2004. Markets drive the specialization strategies of forest peoples. *Ecology and Society* **9**: 1–9.

Russell D. and Franzel S. 2004. Trees of Prosperity: Agroforestry, markets and the African smallholder. *Agroforestry Systems* **61**: 345–355.

Saka J.D.K., Mwendo-Phiri E. and Akinnifesi F.K., 2002a. Community processing and nutritive value of some miombo indigenous fruits in central and southern Malawi. Pp. 164–169 in Kwesiga, F., Ayuk, E. and Agumya, A. (eds.) *Proceedings of 14th Southern African Regional Review and Planning Workshop*, 3–7 September 2001, Harare, Zimbabwe, International Centre for Research in Agroforestry.

Saka J.D.K., Swai R., Mkonda A., Schomburg A., Kwesiga F. and Akinnifesi F.K., 2004. Processing and utilisation of indigenous fruits of the miombo in southern Africa. Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research into Practice. Pp. 343–352 in Rao M.R. and Kwesiga F.R. (eds.) *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihooods in Southern Africa: Putting Research into Practice*: World Agroforestry Centre: Nairobi, Kenya.

Schomburg A., Mhango J. and Akinnifesi F.K., 2002. Marketing of *masuku* (*U. kirkiana*) and *masawo* (*Ziziphus mauritiana*) fruits and their potential for processing by rural communities in southern Malawi. Pp. 169–176 in Kwesiga F., Ayuk E. and Agumya A. *Proceedings of 14th Southern African Regional Review and Planning Workshop*, 3–7 September 2001, Harare, Zimbabwe, International Centre for Research in Agroforestry.

Shackleton, C.M. 2004. Use and selection of *Sclerocarya birrea* (Marula) in the Bushbuckridge lowveld, South Africa. Pp. 77–92 in Rao M.R. and Kwesiga F.R. (eds.). *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihooods in Southern Africa: Putting Research into Practice*: World Agroforestry Centre: Nairobi, Kenya,

Simons A.J. and Leakey R.R.B. 2004. Tree domestication in tropical Agroforestry. *Agroforestry Systems* **61**: 167–181.

Thiong'o M.K., Kingori S. and Jaenicke H. 2002. The taste of the wild: Variation in the nutritional quality of marula fruits and opportunities for domestication, *Acta Horticulturae* **575**: 237–244.

Tiisekwa B.P.M., Ndaikunze B.K., Samson G. and Juma M. 2004. Suitability of some indigenous tree fruits for manufacturing juices and jams in Tanzania. Pp. 331–335 in Rao M.R. and Kwesiga F.R. (eds.). *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihooods in Southern Africa: Putting Research into Practice*: World Agroforestry Centre: Nairobi, Kenya.

Wynberg R.P., Laird S.A., Shackleton S., Mander M., Shackleton C., du Plessis P., den Adel S., Leakey R.R.B., Botelle A., Lombard C., Sullivan C., Cunningham A.B. and O'Regan D. 2003. Marula Policy Brief: Marula commercialisation for sustainable and equitable livelihoods. *Forests, Trees and Livelihoods* **13**: 203–215.