IRVINGIA GABONENSIS

&

IRVINGIA WOMBOLU

A State of Knowledge Report undertaken for
The Central African Regional Program for the Environment

by

Lesley Ainge and Nick Brown

Oxford Forestry Institute
Department of Plant Sciences
University of Oxford
United Kingdom

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1 INTRODUCTION

Irvingia gabonensis and *Irvingia wombolu* are highly valuable and extensively utilised tropical African trees, which were identified as high priority species for state of knowledge reports at the Non-Timber Forest Products (NTFP) workshop held in Limbe in May 1998, funded by the Central African Regional Program for the Environment (CARPE). The CARPE programme aims to reduce deforestation and biodiversity loss in the Congo Basin, particularly through the research and implementation of sustainable harvesting and with an emphasis on improving the livelihoods of local communities. *Irvingia gabonensis* and *I. wombolu* have enormous potential, both in economic terms and as species for sustainable production, so could play a significant role in the conservation of the Congo Basin forests. Improvements in the breeding stock for cultivation, as well as in the cultivation itself are possible and would further increase the benefits and importance of these species.

At present, there is no central point of information for *I. gabonensis* and *I. wombolu*, so with funding from WWF-US, this report has been undertaken for CARPE to draw together all current knowledge, characterise their potential and identify areas for future research. In addition to overviews of the research into each aspect of *I. gabonensis* and *I. wombolu*, original distribution maps and phenological graphs are included that were created from a database set up for this project. Information regarding current research is also given, obtained from others working on these species. It is hoped that this report will serve as a reference work for the two *Irvingia* species, and may help to direct future research and contribute to their development as NTFPs.

2 TAXONOMY AND LOCAL NAMES

2.1 Taxonomic Names

Irvingia gabonensis **(Aubry-Lecomte ex O'Rorke) Baillon.**

Synonyms: *Mangifera gabonensis, Irvingia barteri, I. caerula, I. duparquetii, I. erecta, I. griffoni, I. hookeriana, I. tenuifolia, I. velutina, I. gabonensis var. gabonensis* (Harris 1996, Vivien and Faure 1985).

Irvingia wombolu **Vermoesen.**

Synonyms: *Irvingia gabonensis* var. *excelsa*, *I. gabonensis* var. *wombolu* (Harris 1996).

2.2 Taxonomy

Nooteboom (1966) found the irvingioid group to be well placed as a subfamily within the Simaroubaceae, despite the lack of quassiin and other related bitter principles. Some have agreed with this placing, but others have maintained that *Irvingia* has a closer relationship with other families (e.g. Fernando *et al.* 1995). It is now generally recognised that *Irvingia*ceae is a family in itself, containing the genus *Irvingia* (Harris 1996). The distinction between two forms of *Irvingia gabonensis* was made by Okafor (1975), recognising *I. gabonensis* var. *gabonensis*, which has a sweet edible pulp, and *I. gabonensis* var. *excelsa*, which has a bitter inedible pulp. In 1996, Harris raised the var. *excelsa* to species status, naming it *Irvingia wombolu*.

2.3 Local names

Irvingia spp. are commonly known as the African mango, Dika nut, bush mango or wild mango, which in French (spoken widely in Western and Central Africa) is *manguier sauvage*. There are many local names for *I. gabonensis* and *I. wombolu* , some of which are listed in Table 1 and Table 2. The kernels of these species also have various local names: in Nigeria, they are 'ogbono' in Ibo and 'apon' in Yoruba (Ladipo *et al.* 1996). Dudu *et al.* (1998a) report that Nigerians distinguish between kernels from *I. gabonensis* and *I. wombolu*, referring to the former as 'ugiri' and the latter 'ogbono'. The paste produced from the kernels in Gabon is termed 'dika bread', whilst in Cameroon it is 'etima' (Ndoye *et al.* 1997). Moss (1995) notes that the kernel cake is called 'odika' in Northern Gabon. Tabuna (1997) reports use of the name 'malombo' for *Irvingia* spp. kernels traded to Europe.

Table 1: Local names for *Irvingia wombolu*, from: Vivien & Faure (1996) and Vivien & Faure (1985) and from herbarium specimen descriptions.

Local Name	**Tribe/Country**
Ewewe	Bolon, Gabon
Mbolu	Bamindjere
Moboulou	Bibaya Pygmies
Ogwi	Benin
Olili	Turumba
Ossim	Kiaka
Payo	Bibaya Pygmies

Table 2 Local names for *Irvingia gabonensis*, collated from: Ake Assi (1991); Vivien & Faure (1996); Vivien & Faure (1985); Ndoye & Tchamou (1994) and Tabuna (1997) and from herbarium specimen descriptions.

Local Name	**Tribe/Country**
Aadok	Cwondo
Abisibou	Ny
Aiya iyon	Kiaka
Ando	Mvae
Ando'o	Bulu (or Boulou)
Andok	Bolon, Fang, Gabon
An-Gbere	Temne
Bè	Akyé
Boboi	Mende
Borborou	Abbey, Côte d'Ivoire
Boubwé	Bateke
Bulukutu	Cameroon
Bush mangolo	Bangangte
Bwiba bambale	Dogose

Ebi	Central African Republic
En'doe	Boulou
Eniok	Congo
Kaklou	Baoulé
Kakourou	Gouro
Kplé	Guéré
Mangoron Kurmi	Hausa
Miba	Douala
Mwiba	Bassa
Ndoka Nijaka	Bassa Douala
Nouak	Maka
Ntwa	Baka pygmies
Ogbono	Ibo
Ogui	Benin
Ogwe	Nigeria
Oro	Nigeria
Oroapon	Yoruba
Ororgbije	Yoruba
Péké (or Pékié)	Bibaya Pygmies, Maka
Sakossou	Bété
Uyo	Efik
Wiba	Bassa

3 ECOLOGY AND DISTRIBUTION

3.1 Distribution

Irvingia's preferred habitat is undisturbed lowland tropical forest (Van Dijk 1997). The bush mango tree is better adapted to Utisol soils in high rainfall areas than to less acidic soils (Kang *et al*. 1994), but within these areas the two species differ. Okafor (1975) states that *I. gabonensis* prefers well-drained sites, whilst *I. wombolu* thrives in wetter conditions.

Both *Irvingia* spp. are found growing wild in the humid lowland forests of tropical Africa in Angola, Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon and Zaire (Harris 1996), with *I. wombolu* additionally extending to Senegal (Ndoye *et al.* 1997). Figure 1 is a distribution maps for the two species, created from the NTFP database set up for this project.

Irvingia gabonensis and *I. wombolu* are planted and maintained on farms throughout their range in Central and Western Africa. Planting is common in Nigeria (Ejiofor *et al.* 1987), more predominantly on outlying farms than on compound farms (Okafor 1983). Van Dijk (1997) states that the bush mango has a moderate density in the South of Cameroon (2.1 stems/ha. average, 3.6 stems/ha. maximum), reporting that it has an even distribution and appears in every habitat type. However, Agbor (1994) relates that the density of the species in the tropical moist forest zone (TMFZ) of Nigeria is low, as a consequence of high mortality of younger trees, low recruitment rate into the mature age classes and the absence of intensive cultivation of this species. This may be the case for most areas in which *Irvingia* spp. grow.

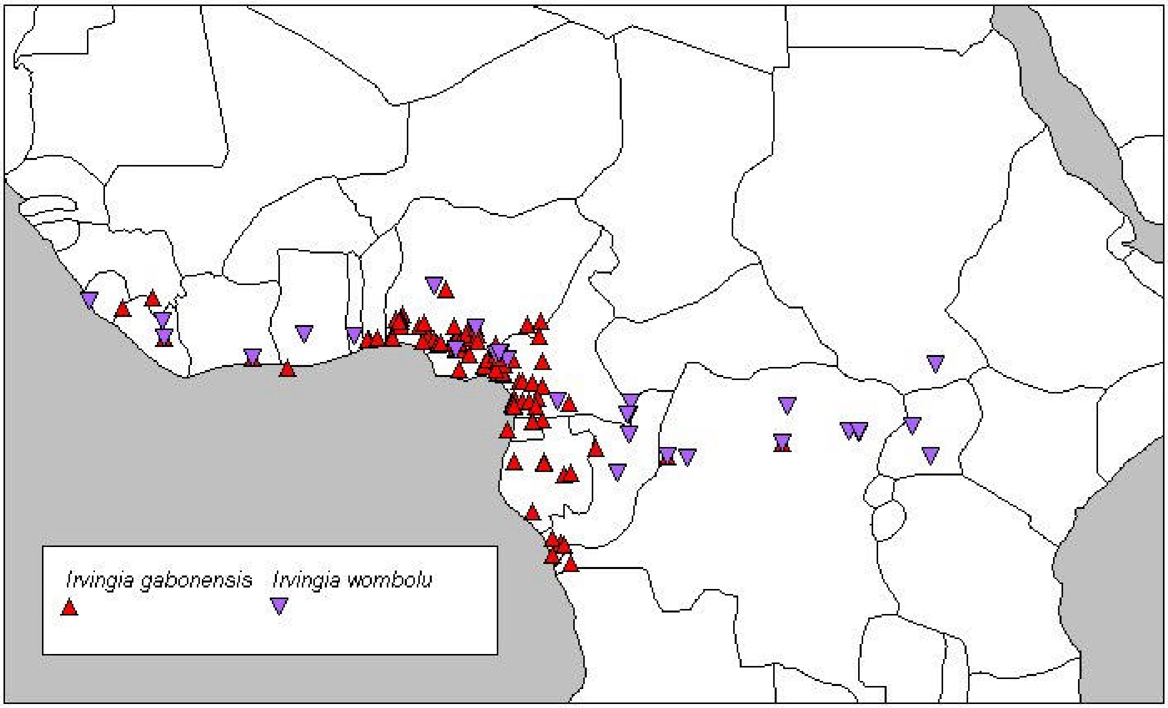

Figure 1 Distribution of herbarium collections of *Irvingia gabonensis* and *Irvingia wombolu* from Kew, Meise, Missouri, Oxford and Wageningen

3.2 Botany

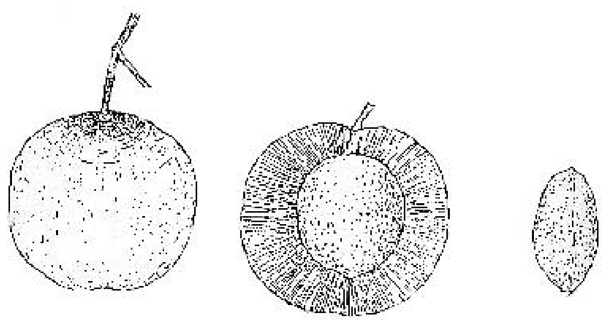

Figure 2 Whole fruit, vertical section and extracted seed of *Irvingia gabonensis* (l-r). Source: Ladipo *et al.* (1996).

Irvingia gabonensis and *Irvingia wombolu* are very similar, and indeed are often difficult to tell apart from herbarium specimens alone (Harris 1996), however there are characteristics that distinguish the two, most noticeably the edibility of the fruit mesocarp. Harris also mentions the density of fibres in the mesocarp, the amount of mucilage in the cotyledons, the size of the endosperm, the height of first branching, the disc shape in unfertilised flowers and the shape of the tree as diagnostic characters. Harris gives detailed botanical descriptions of both species, which are reproduced in Appendix A. Figure 2 shows the fruit and seed of *Irvingia gabonensis*.

3.3 Seed composition

The composition of *Irvingia* spp. seeds has been well studied since they are the most valuable product of the tree and have the most industrial potential. Although the two species' seeds do differ in their composition, the differences are not always found to be significant and some studies fail to identify which species is being analysed. This is particularly so for those that were undertaken before *I. wombolu* was recognised as a separate species, therefore in some cases figures given for *I. gabonensis* are actually for *I. gabonensis* var. *excelsa* (*I. wombolu*). Onyeike *et al.* (1995) report that the crude fat content of *I. gabonensis* seeds is 62.25% ±0.55, proving them to be 'very good oil seeds'. Ejiofor *et al.* (1987, cited in Ejiofor 1994) reported the values given in Table 3 from a chemical analysis of *I. wombolu* seeds.

Moisture	Fat	Total carbohydrate	Ash	Crude Protein	Crude fibre	Vitamin C (mg/100g)	Vitamin A (mg/100g)
11.9	51.32	26.02	2.46	7.42	0.86	9.24	0.63

Table 3 Approximate composition (%) of fresh kernels of *I. wombolu* (*I. gabonensis* var. *excelsa*). Source: Ejiofor (1987, cited in Ejiofor 1994).

Amubode and Fetuga (1984) analysed the amino acids in *I. gabonensis* and produced the figures given in Table 4.

%CP	Trp.	Lys.	His.	Arg.	Asp.	Thr.	Ser.	Glu.	Pro.	Gly.	Ala.	Val.	Met.	Cys.	Ile.	Leu.	Tyr.	Phe.
35.5	1.3	4.9	3.4	10.9	12.1	3.5	3.9	18.8	5.0	5.3	5.3	5.5	1.8	2.4	6.3	7.5	3.8	5.0

Table 4: Amino acid composition of *Irvingia gabonensis*, values in g/16gN. Source: Amubode & Fetuga (1984). (CP = Crude protein; Trp. = Tryptophan; Lys. = Lysine; His. = Histidine; Arg. = Arginine; Asp. = Aspartic acid; Thr. = Threonine; Ser. = Serine; Glu. = Glutamic acid; Pro. = Proline; Gly. = Glycine; Ala. = Alanine; Val. = Valine; Met = Methionine; Cys. = Cystine; Ile. = Iso-leucine; Tyr. = Tyrosine; Phe. = Phenylalanine.)

Omogbai's (1989) study of the lipid and fatty acid composition of Nigerian tropical seeds included *I. gabonensis*. Table 5 and Table 6 give his results.

Total lipids (mg/g DM)	FA	TG	MGDG	DGDG	SL	PG	PC	PE	PI	DPG	Yield (%)
658 ±1	8 ±4	913 ±3	5 ±3	10 ± 1	10 ±2	8 ±2	25 ± 2	2 ±1	8 ±1	10 ± 1	99.2

Table 5 Lipid composition of *Irvingia gabonensis* seeds, values in mg/g. Source: Omogbai (1989). (FA = unesterified fatty acids; TG = triacylglycerols; MGDG = monogalactosyldiacylglycerol; DGDG = digalactosyldiacylglycerol; SL = sulphoquinovosyldiacylglycerol; PG = phosphatidylglycerol; PC = phosphatidylcholine; PE = phosphatidylethanolamine; PI = phosphatidylinositol; DPG = diphosphatidylglycerol; Yield = sum of weights of individual lipids expressed as a percentage of the weight of the total lipid taken for fractionation.)

C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:1	Others
1.0	14.6	5.5	8.6	20.5	21.5	21.3	1.3	5.7

Table 6: Fatty acid composition (% of total lipids) of the seeds of *Irvingia gabonensis*. Source: Omogbai (1989).

3.4 Ecology & Phenology

Local people gather the fruits of *I. gabonensis* and *I. wombolu*, and many other mammals consume the fruits in the forest. *I. gabonensis* fruits compose a significant part of the diet of forest elephants (Loxodonta africana cyclotis) (Tchamba and Seme 1993) and Harris (1996) details squirrels and other rodents, as well as red forest pigs (Potamochoerus porcus) opening the fruits to feed on the seeds. It has also been reported that gorillas (Gorilla gorilla) eat the fruit (Howes 1948). Wild bees make honey from the nectar of *I. gabonensis* (Agwu and Akanbi 1985).

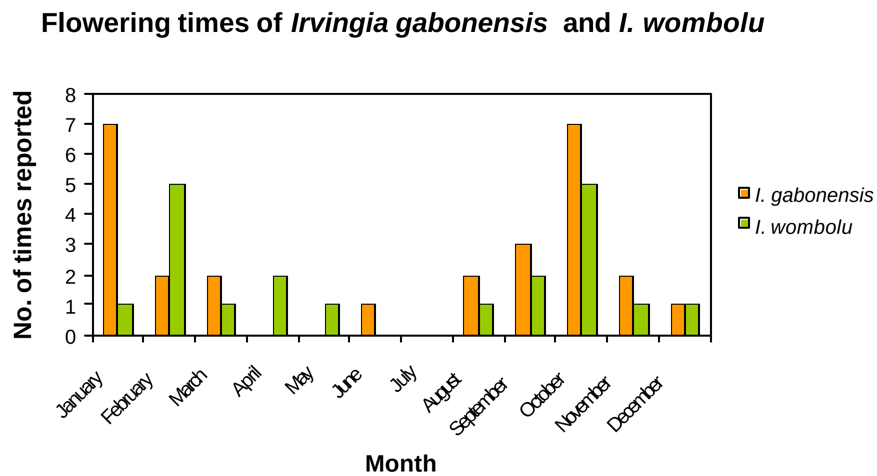

Figure 3: Flowering times of *Irvingia gabonensis* and *I. wombolu*, from herbarium specimen data.

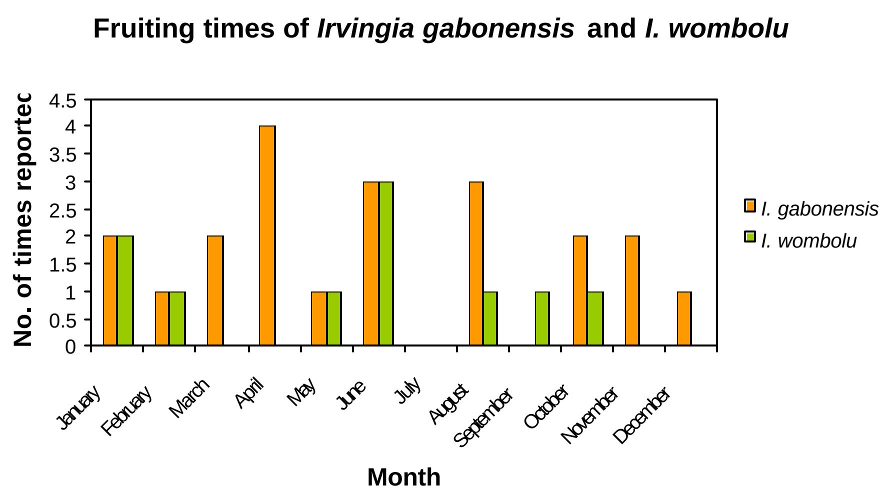

Figure 4: Fruiting times of *Irvingia gabonensis* and *I. wombolu*, from herbarium specimen data.

These trees are insect pollinated (Tutin and Fernandez 1993). Ladipo *et al*. (1996) state that very little is known about the mating systems and gene flow of *Irvingia* spp., except that *I. gabonensis* is known to have hermaphroditic flowers. They also report uncertainty about the level of outbreeding in this species, but if a recent study indicating that 100% outbreeding is correct (unpublished, cited in Ladipo *et al.* 1996), it implies that *I. gabonensis* is highly heterozygous.

The phenology of these two species differs considerably. *I. gabonensis* generally flowers in February-March (Agwu, 1985) and fruits in the rainy season from July-September (Ladipo *et al.* 1996), whilst *I. wombolu* flowers in October (Okafor 1975) and fruits in the dry season around January-March (Ndoye *et al.* 1998, Okafor 1975). Flowering and fruiting times vary over geographic range. In most areas, *Irvingia* spp. fruit once a year, but biannual fruiting is not uncommon (Tutin and Fernandez 1993) and some trees only produce fruit every other year (Ladipo *et al.* 1996). In Nigeria, *I. gabonensis* can fruit twice per year: once in January-February and then again in June-August and within these fruiting seasons trees fruit earlier or later depending on region (Ladipo *et al.* 1996). Okafor (1975) also describes cultivated trees that fruit in both May-July and September-October. Figure 3 and Figure 4 show the flowering and fruiting times for each species, produced from the information in the NTFP database. The flowering times are not distinct between the two species, as might have been expected from the information given by others and I can think of two reasons why this is the case. Firstly, some of the herbarium specimens labelled as *I. gabonensis* may have actually been *I. wombolu*, but were assigned to *I. gabonensis* before *I. wombolu* was recognised as a separate species. Secondly, since both species may flower twice a year, specimens from the regions where biannual flowering occurs are likely to be included, creating an overlap of flowering times. Nonetheless, the graph shows two clear peaks for flowering – one in January and one in October, corresponding to the peak of the dry and rainy seasons. The fruiting times are less well defined into seasons, indicating that fruit is available on one of the two species nearly all year round. *I. wombolu* appears to have two fruiting periods: from January-February and May-November. *I. gabonensis* is reported to fruit in all months except July and September, peaking in April.

Irvingia trees usually reach maturity and begin flowering at 10-15 years of age (Ladipo *et al.* 1996, Moss 1995). However, much earlier fruiting has been reported and Ladipo *et al.* (1996) describe trees that produced fruit at age six. A study of the productivity of *Irvingia* spp. indicates that *I. gabonensis* is more productive than *I. wombolu* at the same age and in the same location (Kang *et al.* 1994). The researchers also observed that branching intensity seems to be a major factor in determining productivity.

4 USES OF *IRVINGIA* SPECIES

4.1 Timber and Wood

Bush mango wood is used by locally for construction (Leakey 1999b). It is a fine-grained, hard, heavy timber (Ayuk *et al.* 1999), conferring strength and durability; these characteristics are recognised and utilised (Agbor 1994). The wood is also used for making poles and stakes (Ayuk *et al.* 1999), whilst live branches are made into walking sticks or thatched roof supports (Agbor 1994). Dead branches are used as firewood (Ayuk *et al.* 1999).

4.2 Fruits

The juicy fruit pulp of *I. gabonensis* is rich in vitamin C and is widely reported to be consumed as a dessert fruit or snack throughout Western and Central Africa (Ejiofor 1994, Leakey and Newton 1994, Vabi and Tchamou 1997, Vivien and Faure 1996). Agbor (1994) relates that the average adult may eat over 20 ripe fruits at a time. *I. gabonensis* pulp can be used for making jam, jelly and juice (Ejiofor 1994, Okolo *et al.* 1995). The fruit is sometimes also fed to pigs (Ayuk *et al.* 1999). The fruit pulp of *I. wombolu*, however, is bitter and tastes of turpentine, so it is not edible (Ejiofor 1994).

4.3 Seeds

The kernels of *I. gabonensis* and *I. wombolu* are classed as oilseeds. They are ground with a pestle and mortar or on a stone into a paste or cake called 'dika bread', which is used as a soup, stew or sauce additive, for flavouring and thickening (Agbor 1994, Leakey and Newton 1994, Vivien and Faure 1996). The kernels are highly valued for the slimy consistency they produce. Okafor (1975) notes that whilst kernels from both *Irvingia* spp. are used in soup-making, *I. gabonensis* kernels can only be used when fresh since they become too slimy over time. Dika bread may be sun-dried so that it can be stored (Vivien and Faure 1996). *Irvingia* kernels form an important part of the West and Central African diet, providing carbohydrate and protein (Onyeike *et al.* 1995). Agbor (1994) reports that the kernels may be roasted to enhance their flavouring effect, and that crushed pieces of the roasted kernels may be used in frying vegetables. The kernels of *I. wombolu* are consumed by the Baka pygmies in South-east Gabon (Vivien and Faure 1996) and have a slightly bitter after-taste, although their overall flavour is not unpleasant (Howes 1948).

Fat extracted from the kernels can be used for food applications, such as in margarine or cooking oil, and is also suitable for soap, cosmetics and pharmaceuticals (Ejiofor *et al.* 1987). Flour can be produced from the kernels, but degrades within 6-9 months unless defatted. Defatted flour is still acceptable in terms of its colour, taste, texture and drawability after 9 months storage in ambient conditions, and is more viscous, with greater emulsifying properties than undefatted flour (Ejiofor *et al.* 1987). Due to its ability to form gels at a lower concentration than many other oilseed flours, Giami *et al.* (1994) conclude that *Irvingia* kernel flour would be very effective in many industrial food applications that require a thickening agent. Improvements in drawability and possible storage time have enabled the flour to be considered for a range of processed products, particularly 'Ogbono' cubes. These are produced by cubing and packaging the flour, thus giving them a longer shelf life, and are sold as a convenient cooking ingredient. Ejiofor (1994) recommends using flour produced by milling the seed testa in formulating feeds for livestock.

4.4 Other Uses

Agbor (1994) states that the roots, leaves and bark of *Irvingia* spp. are used medicinally, however others mention only the bark. *I. gabonensis* bark is mixed with palm oil for use in the treatment of diarrhoea and is taken by women to shorten their breast feeding period (Ndoye and Tchamou 1994). It is also administered for colic and dysentery (Okolo *et al.* 1995) as well as for hernias, yellow fever and as an antipoison (Ayuk *et al.* 1999). Ndoye and Tchamou (1994) report that the bark has antibiotic properties for healing scabby skin and, particularly when boiled, it can be given as a painkiller for toothache. Okolo and co-workers (1995) investigated the analgesic properties of the bark after finding that the Mende tribe in Sierra Leone grind it and form it into a paste with water which they use directly on the skin for pain relief. They found that it contains a narcotic-type analgesic agent and may also contain a non-narcotic active agent.

Fresh bark can be used to confer a bitter taste to palm wine if pieces are kept in the wine containers during tapping (Ndoye and Tchamou 1994). Mbakwe (1983) documents that stems from *I. gabonensis* are among several species harvested by tribesmen as 'chewing-stick' which is chewed to help keep their teeth clean. Farmers may collect leaves from bush mango trees as fodder for their animals (Ayuk *et al.* 1999).

4.5 Potential Uses

Much of the potential for *I. gabonensis* and *I. wombolu* lies in the expansion of current uses, particularly of the kernels, to industrial levels. There are, however, some novel applications that have been suggested by researchers. *I. gabonensis* fruit can produce a good quality wine, comparable in colour, flavour, sweetness and general acceptability with a selected German wine. The wine had 8.12% alcohol content after 28 days fermentation in a trial set up by Akubor (1996). This seems like a viable future product of bush mango, particularly after the success of other African alcoholic drinks made from native fruits, such as 'Amarula' made from Sclerocarya birrea fruits. Joseph (1995) lists the potential industrial applications of bush mango kernel fat, including cooking oil, margarine, perfume, soap and pharmaceuticals. He notes that once the fat has been extracted from the kernels, the residue still possesses the consistency and thickening properties required for soup-making, so there are no wasteful by-products from the fat extraction process, both the fat and the residue can be used. Aside from its role as a thickener, the residual kernel cake could also be used as a binder in food or pharmaceutical products (Joseph 1995). Ndjouenkeu *et al*. (1996) extracted the polysaccharides from *Irvingia* kernels and from an analysis of their properties concluded that they have potential as an industrial gum. Figure 5 outlines the product development of *Irvingia* kernels.

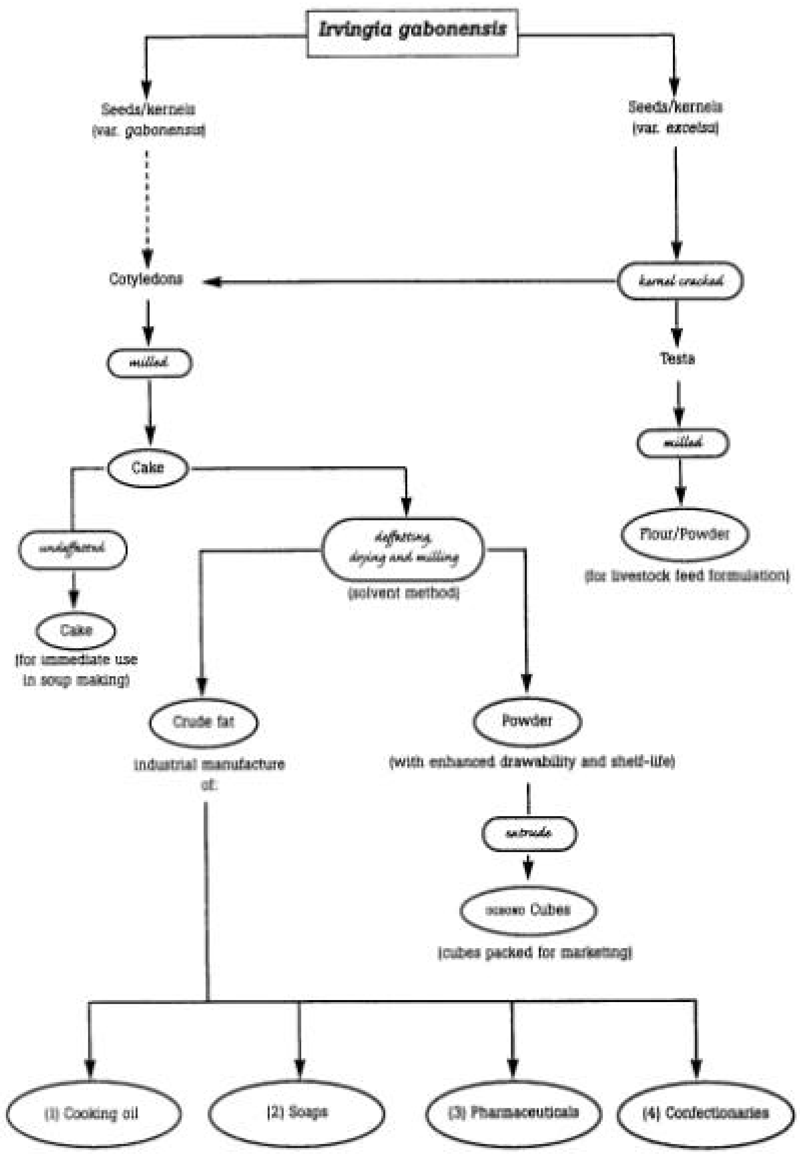

Figure 5: Product development from seeds of *Irvingia* spp. (var. *gabonensis = I. gabonensis* and var. *excelsa = I. wombolu*). Source: Ejiofor (1994).

I. gabonensis (known as 'dikanut' in these studies) has been studied as a dietary fibre for reducing the hyperglycemic effects and lipid metabolism disruption caused by diabetes mellitus. Adamson and his team (1986) found that giving diabetic patients a dose of dikanut preparation daily for 4 weeks reduced blood glucose levels to normal and additionally increased the activity of three ATPases, that usually fall significantly below regular levels in diabetics. Dikanut could therefore be a suitable alternative to Guar, another viscous dietary fibre that has been shown to have similar effects but is unacceptable to patients at the dosage necessary. These dietary fibres work by delaying gastric emptying and thus reducing the intestinal sugar absorption rate. This reduced rate improves the sensitivity of the tissues to insulin, resulting in increased glucose uptake. Adamson continued his studies with Omoruyi (1994) to try to work out how *I. gabonensis* alters the lipid metabolism of diabetics. Adamson and his workers had previously found that the blood glucose and lipid levels of type II diabetic patients could be improved by a dose of 4g of dikanut per 100g of food. Omoruyi and Adamson examined the plasma and liver lipids of streptozotocin-induced diabetic rats after 4 weeks in a dikanut-supplemented diet. They found that the dikanut affected phospholipid distributions and concluded that this may be how it helps in the hepatic control of plasma lipids. Joseph (1995) also notes that dikanut could be employed as a substitute for easily hydrolysed carbohydrates in diabetic foods.

5 CULTIVATION, HARVESTING AND PROCESSING

5.1 Growing *Irvingia* spp.

At present, most farmers maintain mature bush mango trees that are already growing on their land and will also transplant wild seedlings onto their farm or grow up new seedlings (Ayuk *et al.* 1999). They select seeds from trees that are known to produce high yields of good fruit, either on their land or from a neighbour. Alternatively they may plant market-bought seeds, however, the most common source of new stock for cultivation is the forest (Tchoundjeu *et al.* 1997). Germination of *I. gabonensis* seeds takes upwards of 14 days and first requires that the seeds are extracted from the fruit and dried for at least 2 days. Okafor (1997) reports 80% germination for seeds treated in this way. Bush mango trees grown from seed may take over 10 years to start producing fruit and although growing seeds may be the easiest way to improve cultivation, farmers would like to see a financial return much sooner (Moss 1995). Faster

propagation techniques are also needed to produce trees for the selection of desirable phenotypes which can then be used for further breeding. Hence, it has been recognised that if *Irvingia* spp. are to be domesticated, and if production is to be increased, then faster and more successful propagation methods are needed. Several workers have investigated different methods of propagation for *I. gabonensis* and *I. wombolu*.

Shiembo *et al.* (1996) experimented with different methods for growing cuttings taken from mature trees. They found that the best medium for rooting is sawdust or a similar organic substrate and that the cuttings must have a leaf area of at least 80cm2 to survive and grow well. Applications of auxins (IBA) make no significant difference to growth and therefore do not seem to be necessary. This technique is ideal for farmers in tropical Africa because it does not require electricity or piped water. However, according to Tchoundjeu *et al.* (1997), propagation by stem cuttings is notoriously difficult because the cuttings often do not root. Tchoundjeu investigated a technique that he claims to be preferable – marcotting. In this technique, also known as air layering, the branch of a mature tree is bark girdled and the girdled ring is wrapped in a damp medium, inducing rooting. Despite a low rooting success rate (30%) and an even lower survival rate (10%) he states that this is still a useful technique, which can be improved. Rooting hormones, more careful handling of the rooted propagules and initial growth under a non-mist propagator could all significantly increase the survival rate of the propagules.

A further vegetative propagation technique that has been successfully used for *Irvingia* spp. is bud grafting. Okafor (1997) claims that this method, where a bud is grafted from a mature tree onto a seedling, ca reduce the fruiting age of the tree to 2-4 years, and also lower the height of the fruit set from 8 metres or more to 1-3 metres. Leakey *et al*. (in press) comment that this technique may not be as successful as propagation by stem cutting, however, because of problems with grafting incompatibilities. These studies into possible propagation techniques show that *Irvingia* spp. can be propagated by all of the common methods. In Nigeria, workers have detailed standard methods for growing *I. gabonensis* in nurseries (Leakey 1999). Developing propagation techniques with high success rates and multiplication rates is crucial for the production of superior planting stock for farmers and for the domestication process. IRAD (Institut de la Recherche Agricole pour le Développement) and ICRAF (International Center for Research in Agroforestry) are currently researching into improvements of existing propagation methods in Cameroon and Nigeria (Leakey *et al.* in press).

5.2 Management and Harvesting

Farmers collect fruits from their own trees as well as wild and semi-wild forest trees. Cultivated trees are pruned and fertilised and some pest control is carried out (Ayuk *et al.* 1999). The gathering of *Irvingia* fruits is usually done by women, except when climbing is necessary (Ndoye *et al*. 1998). Vabi and Tchamou (1997) do, however, report that tribesmen in the Korup National Park of Cameroon join their wives in bush mango collection when they are out trapping. Harvesting of fruits is sustainable and non-destructive, although Ndoye *et al.* (1997) point out that it may have a long-term effect on the tree and could affect the population structure of *Irvingia* spp.. Bark collection does cause damage to the tree, but bark is not harvested in large quantities, so should not affect productivity significantly.

5.3 Processing

There are several reported methods for the obtaining the kernels from *Irvingia* fruits. Ejiofor (1994) writes that traditionally the fruits are piled up in heaps and left to ferment before the seeds are extracted. According to Ladipo *et al*. (1996) the seeds can either be taken out wet from the fermented fruits, or the fruit may be sun dried first. As an alternative to fermentation, the fruits can be split open with a cutlass to reveal the hard seed inside (Ayuk *et al*. 1999). Once the seeds have been collected they are dried, either in the sun or over a fire. They are then cracked open and a knife is used to remove the two white cotyledons (kernels). The kernels are dried further to remove all moisture and can then be stored or processed ready for use in food (Ejiofor 1994, Joseph 1995). It is important that the kernels are fully dry, unless they are being used immediately, because fresh kernels quickly discolour and turn mouldy. In South-west Nigeria, bush mango kernels are normally taken fresh from the fruit, before drying (Ladipo 1997). In Cameroon, often 3 or 4 women meet to process the kernels (Ayuk *et al*. 1999), which are extracted from the fruits once they have already been dried, so little further drying is necessary (Ladipo 1997). Ladipo *et al.* (1996) warn that all the methods used for kernel extraction are difficult, hazardous and time-consuming.

The dried kernels are ground with a pestle and mortar before being added to food (Agbor 1994). Potential industrial applications of *Irvingia* kernels require that they are ground and that the fat is extracted and on an industrial scale (Leakey 1999). Grinding and fat extraction would involve processing machinery. Okolo (1994) describes a pilot plant for the grinding, fat extraction, mixing, cubing and packaging of kernels into Ogbono cubes. He estimates that it could produce 20,000 cubes per hour and would require 256 metric tonnes of bush mango kernels per year.

5.4 Storage

The fresh fruits of *I. gabonensis* have a shelf life of less than 2 days if picked when ripe and not more than 10 days if harvested at the mature green stage due to high respiration rate, moisture loss and microbial attack (Joseph and Aworh 1991, 1992). Poor storage conditions and handling, as well as pest attack, diseases and deterioration contribute to high losses of saleable fruit. Initially, Joseph and Aworh (1991) tried to lengthen the shelf life of mature green bush mangoes by refrigerating them at 12-15ºC – a common method for delaying ripening. This resulted in chilling injuries such as pitting and black spots, which would reduce saleability considerably, making this an inviable option for storage. They then trialed several different post-harvest storage methods including dipping, wrapping and waxing the fruit, to see which was the most effective (Joseph and Aworh 1992). They found that the longest shelf life resulted from briefly submerging the fruits in a hot sulphite dip (commonly used in the food industry) and then wrapping them in PVC film. Hot water or other hot chemical dips used in conjunction with waxing or packaging in wrapped boxes were also effective combinations for enhancing shelf life at 22-35ºC and 70-95% relative humidity, normal storage conditions in Africa.

Stored *Irvingia* seeds keep for up to a year (Ndoye *et al.* 1997), but are susceptible to pests. One major pest is the merchant grain beetle (Oryzaephilus mercator) which lays its eggs between the testa and cotyledons of the seed or in cracks in the cotyledons, so that when the larvae hatch they can consume the cotyledons (Dudu *et al.* 1998b). The testa could be fully removed to reduce the number of preferred oviposition sites, but this may allow other pests to attack. More careful handling of the seeds to prevent cracks will both help to prevent grain merchant beetle infestation and keep the value high, since damage reduces sale price. The beetle has a long life span as well as fast population growth, so it is essential that its presence is detected early to prevent huge losses. Dudu *et al.* (1998b) suggest that a diethyl ether extract of *I. gabonensis* could be used to attract the beetle, either to detect it or to attract it away from stored oilseeds, including *Irvingia* seeds themselves.

The various products of *Irvingia* kernels have differing length shelf lives. The sauce made from fresh kernels can be kept for 3 or 4 days, whilst 'dika bread' paste made from crushed, dried kernels can be stored for over a year (Ndoye *et al.* 1997). *I. gabonensis* fat, extracted from the kernels, has been stored for more than a decade with no adverse changes in it properties because it contains natural anti-oxidants that hinder oxidative decay (Okolo 1994).

5.5 Quality Control

Irvingia kernels are the most important product of the bush mango tree. As trade increases, quality standardisation will become central to setting prices for producers and traders. Ladipo (1997) suggests four quality classes (A – D) for bush mango kernels, based firstly on visual characters including the size and thickness of the kernel, its colour and the extent of damage or blemishes, and also on qualities such as oil content, flavour and consistency, which affect its primary use in cooking. These factors determine the value of the kernels to the consumer. Ladipo notes that *I. gabonensis* kernels are often mixed with those from *I. wombolu* due to the abundance of *I. gabonensis*, but since they are less desirable than *I. wombolu* kernels they reduce the overall value. Therefore he emphasises the importance of separating the two species to maintain high market prices.

6 MARKETS AND TRADING

Irvingia trees are a valuable source of income for West and Central African farmers. The fruits are sold, but by far the most important product is the kernels, which fetch a price several times higher than the fruits (Ayuk *et al.* 1999). The trade in kernels not only benefits the producers financially, but also generates income for traders. *Irvingia* kernel markets extend to local, regional and international levels and there is even inter-continental export. ICRAF (cited in Ladipo 1997) reported that in 1975 the market for kernel products was worth in the region of US$50 million. This market is still growing.

6.1 Production Levels and Sale Prices

Fresh fruits of both *I. gabonensis* and *I. wombolu* are marketed locally where they are produced and are traded to non-producing areas. Agbor (1994) found that prices were higher in non-producing areas of Nigeria than in producing areas, as would be expected. In producing areas *I. gabonensis* fruits were more expensive than *I. wombolu* fruits, however in non-producing regions this situation was reversed. He reports that the value of fruits increased immensely between 1986 and 1994. In some northern areas of Nigeria, he notes that prices are astronomical, due not to low fruit production, but to the absence of sufficient storage facilities and the high costs of transportation. In the Korup National Park, in Cameroon, difficulties in transporting bush mango fruits to the suburban markets because of nearly impassable roads during the peak season reportedly reduced the prices that producers received (Vabi and Tchamou 1997). *I. gabonensis* fruits are normally bought for their juicy edible pulp, but *I. wombolu* fruits are purchased for their kernels.

Since *I. wombolu* kernels are more highly cherished for cooking than those of *I. gabonensis*, farmers should earn additional income from *I. wombolu* trees. According to Ndoye *et al.* (1998), however, there is presently no distinction between the two species' kernels on the market. This is likely to change as quality controls are introduced (see p.11). A farmer can expect to gain about US$300 annually through kernel sales from a mature *I. wombolu* tree (Uzo 1980, cited in Okolo 1994). Despite the high value of the products, production is generally at the subsistence level (Agbor 1994). In a study in the South of Cameroon, for example, van Dijk (1997) found that only 20% of the bush mango harvest was sold, yet Malleson (1997) reports that forest spices, including *Irvingia* spp., are the main income generators for women in the Korup Forest of Cameroon. It seems that although farmers only sell a small percentage of their harvest, those sales alone account for a relatively large proportion of their annual income. This low level of marketing of *Irvingia* products is due to a lack of bush mango trees and hence an inadequate supply of produce (Agbor 1994). Bush mango is important to the food security of Central and West African people (Ayuk *et al*. 1999), so unless productivity is increased, there will not be a large enough surplus over the subsistence needs to meet the demand for *Irvingia* products in the markets. Vabi and Tchamou (1997) emphasise this point: that only once food security is improved will there be a base from which farm income can be increased.

The price that producers get for *Irvingia* fruits and kernels depends on the location of the market and fluctuates greatly with seasonal availability. Ayuk *et al.* (1999) collected data from three divisions in the humid lowlands of Cameroon to gauge the economic value and potential of *I. gabonensis* products (Table 7).

These figures show the extent of price variation over the season – high prices at the start when availability is low, then reduced prices as the quantity of product increases, and finally a price increase as the products become scarce at the end of the season. Leakey (1999) also reports that the price of kernels in West Africa varies with the season between £1 (≈US$1.6) and £3 (≈US$4.8) per kg. Ndoye *et al.* (1998) examined the sales value of *Irvingia* spp. in 28 markets in the humid forest zone (HFZ) of Cameroon and found that over 29 weeks, the total value of sales was 34,633,100 CFA francs (≈ US$70,000). The margins gained by the traders were 30% of the total value of sales. These high market values are repeated in Rio Muni, in Equatorial Guinea, where Sunderland (1998) reports that *Irvingia* spp. seeds are sold more widely than any other forest product. Again, sales and prices are greatly influenced by the seasonal availability of bush mango seeds. Sunderland states that in June-September, when *Irvingia* products are in season, 100 CFA francs will buy 40 seeds, whereas during September-December, at the end of the season, the same money will only buy 20 seeds.

Mean annual production	Division					
	Lekié		Haut Nyong		Mvila	
	Fruits	Seeds	Fruits	Seeds	Fruits	Seeds
Total	112	32	835	27	165	110
Sales	23	15	328	12	90	56
Consumption	54	17	456	15	73	49
Other (e.g. gifts)	35	0	51	0	2	5
Value:						
Beginning of season price	130	705	25	230	135	695
Middle of season price						
End of season price	40	300	15	135	45	355
	80	585	10	230	70	325

Table 7: Mean annual production estimates (in kg/grower or collector) and value of production (in CFA francs/kg) of *Irvingia gabonensis* fruits and seeds in the humid lowlands of Cameroon. After: Ayuk *et al.* (1999).

Although fresh kernels are highly seasonal, the production of dried kernel cake ('odika') ensures that bush mango is available all year round. Moss (1995) reports that odika is traded from the Côte d'Ivoire to the Congo. He found that in February 1994, a 100kg sack of odika was selling at US$76 wholesale price in Libreville, Gabon, whilst in Bitam the retail price was US$1.51 per kg. Yembi (1997) also reports from Libreville that 100 to 5000 grams of odika can be purchased for 1000 to 25,000 CFA francs. Agbor's study in Nigeria (1994) records sale prices for dried and fresh seeds, discovering that seeds follow the trend of odika, being more expensive in the dry season than in the rainy season, and that irrespective of season, dried seeds are more expensive than fresh seeds.

6.2 Local and Regional Markets

The marketing system for *Irvingia* spp. products is described in detail by Agbor (1994). Initially, produce is bought from the producers by country buyers, then it is sold to wholesale distributors, who sell to retailers. Products may pass through the hands of several intermediaries before reaching the retail markets, so retail prices are high to accommodate the profit taken by each middleman. Since this informal marketing system is already in place, increases in production should find no problems with market structure and it will not be necessary for governments to create a formal system (Moss 1995). It may be beneficial to consumers to reduce the number of intermediaries to a minimum in order to keep prices down, but on the other hand the *Irvingia* trade could support large numbers of wholesale and distribution workers and this may be a more preferable situation than lower retail prices. There is a demand for *Irvingia* products in urban areas as well as in the country, and much of the trade focuses on moving produce from rural areas into the towns and cities. Where the demand in a country cannot be met, produce is imported from neighbouring countries.

6.3 International Markets

The international trade in *Irvingia* kernels has resulted in even higher profit margins for traders (Ndoye *et al*. 1998). There is a lack of statistics for the volume of international trade, but the trade routes for *Irvingia* spp. are widely known. Cameroon is a major producer, exporting to Gabon and Equatorial Guinea in particular (Ndoye *et al.* 1998, Sunderland 1998). Equatorial Guinea in turn supplies kernels to Gabon (Sunderland 1998, Yembi 1997). Ayuk *et al*. (1999) report that in West Africa the main exporters are Cameroon, Nigeria and Côte d'Ivoire, trading to Gabon, Nigeria, Liberia and Sierra Leone. The demand for kernels in Southern Nigeria alone is around 80,000 tonnes per year (Ndoye *et al*. 1997) and this country serves as both a source and destination for trade.

The export of *Irvingia* products to other continents has already begun. Ladipo (1997) mentions the sale of processed kernels to the United Kingdom and America, and Tabuna (1997) reports on the trade to Europe. According to Tabuna, there are markets for African NWFPs in France and Belgium which supply African immigrants with bush mango kernels, mainly from Cameroon and Congo. He estimates that there are 100,000 potential consumers in this market. The kernels that are imported must be dried, since Tabuna reports that they are available year-round. This inter-continental trade not only generates higher revenue for producers and traders in Africa, but also creates employment for traders in the destination countries.

6.4 Economic Potential

Reports in the *Irvingia* trade indicate that *Irvingia* is a very popular product, which is becoming more scarce as productivity fails to keep up with increasing demand. The potential and demand for large scale production is high and Agbor (1994) argues that it would have significant positive effects. Firstly, if the volume of trade increases, market efficiency will also increase due to improvements in infrastructure, particularly since governments will be more willing to provide suitable roads, water and storage facilities. Secondly, the economy will be further enhanced by greater demand for labour, packaging plants and other industrial products required in the *Irvingia* trade. Agbor points out that for large scale production to occur, however, farmers will need credit to spend on improvements to existing production methods. This creates a circular argument – farmers require more funds to increase production and governments are only likely to help if the volume of trade is greater than it is at present. Thus it is important that the potential of *Irvingia gabonensis* and *I. wombolu* is recognised now and a case made for domestication and improvements to the current trade system, so that the producers can be assisted in raising production to meet demand.

Sunderland (1998) reiterates that there is high and increasing demand for NWFPs in Central Africa, bush mango included. Ladipo (1997) also describes the market for *Irvingia* kernels as 'growing steadily'. The promotion of *Irvingia* spp. products, particularly new products and those that are under-exploited at the moment, will increase the sale of bush mango even further. Ladipo even considers that the development of *Irvingia* kernels as a product could be a model case for the development of other African NWFPs.

7 SUSTAINABILITY ISSUES

7.1 Constraints to *Irvingia* spp. promotion

The constraints on the development of *Irvingia* spp. products are applicable to most NWFPs. Firstly, research is crucial to the development of bush mango as a product and for domestication of the species. The problem lies in the fact that tree crops do not clearly fall within the remit of forestry, agronomy or agroforestry bodies (Moss 1995). Unless the confusions over funding for research are resolved, this could hinder the progress of development. Secondly, as Agbor (1994) points out, there are local and imported substitutes for *Irvingia* kernels that are currently cheaper. As long as *Irvingia* can be shown to be a viable competitor on the market in terms of its quality and cost, then larger scale production is possible. Thirdly, the labour and time involved in harvesting are likely to constrain the number of trees that each farm can maintain. Improved kernel extraction methods would reduce this problem (Van Dijk 1997). Finally, farmers may be unwilling to invest in bush mango trees unless they are guaranteed a price for the produce. It is possible that if many farmers began to produce *Irvingia* products on a large scale, then supply would exceed demand and prices would fall. It may be necessary for governments to offer incentives, such as fixed minimum producer prices, in order to expand on the current productive capacity of *Irvingia* spp. (Agbor 1994).

7.2 Suitability of *Irvingia* spp. for Agroforestry

Farmer preference surveys conducted by ICRAF have identified *I. gabonensis* as the top indigenous fruit for domestication (Leakey and Newton 1994). In a study of under-exploited tree crops, Moss (1995) also concluded that bush mango was one of two species that ‘presented the best opportunities for development intervention’. Leakey (1999b) lists *I. gabonensis* among the ‘Cinderella’ species, that are ideal agroforestry trees because they are already recognised by local people and found in local markets, and since they are indigenous and therefore well adapted to the region.

Irvingia spp. have positive effects on the soils in which they grow, for example reducing soil bulk density and increasing levels of organic carbon and exchangeable potassium and magnesium ions. This makes them very suitable for use as agroforestry trees in a multistorey crop set-up (Kang *et al.* 1994). One of the major incentives for selecting *Irvingia* spp. to be developed for agroforestry is that a huge amount of variation exists within the two species that can be exploited for selection of superior breeding specimens. Tchoundjeu *et al*. (1997) list variations in the fruit (quality, taste and size) as well as in the size of the kernels, the timing of fruit production and in the maturation process as important characters with the potential for improvement. Leakey and Newton (1994) also comment on the high likelihood of favourably altering the season and pattern of fruiting and increasing the yield of trees such as *I. gabonensis*. Assessment of the genetic variation in tree, fruit and kernel properties has already been initiated and is described in the next section.

Farmer knowledge is very important in the selection of trees with potentially suitable genotypes for further breeding. Malleson (1997) and Okafor (1997) both emphasise the need for ethnobotanical information to be used in directing sustainable forest management and agroforestry. Farmers know a great deal about the individual *Irvingia* trees on their land, and this knowledge will greatly aid tree selection. Moss (1995) report that farmers in Gabon are able to identify which trees bear large fruit, which fruit early and which are consistent in fruiting each year, among other useful characteristics. In summary, these two *Irvingia* species are very favourable for agroforestry and have enormous potential.

7.3 Potential Due to Genetic Variation

If *I. gabonensis* and *I. wombolu* are to be improved as agroforestry trees and potentially domesticated, natural variation between trees must be recognised and utilised. Only characters that are determined genetically are of interest, since only these are heritable. Akubor (1996) describes existing bush mango trees as slow growing and poor yielding, and Moss (1995) identifies slow maturation as an impediment to the choice of *Irvingia* spp. for planting.

Nevertheless, as described in the previous section, *Irvingia* spp. have great potential for improvement due to the extent of natural variation in the species. The amount of variation available has been revealed partly from observations of existing trees and partly from studies of genebank specimens.

Three live genebanks for *I. gabonensis* and *I. wombolu* have been created, containing seeds considered by farmers in Gabon, Cameroon and Nigeria to be from superior trees. These germplasm collections are at Mbalmayo in Cameroon and at Ibidan and Onne in Nigeria (Tchoundjeu *et al.* 1997). Knowledge of the genetic variation of the bush mango species resulting from studies of these collections will allow genotypic selection of individuals for vegetative propagation, as suggested by Ladipo *et al*. (1996) to 'promote the domestication process'. Genetic studies of diversity in *I. gabonensis* and *I. wombolu* are possible using seven nuclear cleaved amplified polymorphic sequences (CAPS) that were found by Lowe *et al.* (1998) and which are suitable for phylogeographic analysis. Leakey *et al.* (in press) report that Lowe and his co-workers (in prep.) have found the centre of genetic diversity for each *Irvingia* species, which for *I. gabonensis* is around Ebolowa in Southern Cameroon and for *I. wombolu* is in South-east Cameroon and Western Nigeria.

7.4 Desired Characteristics of Bush Mango

Characters that farmers would like to see improved include fruit quality and yield, earlier maturation of the trees, a longer period of fruit availability and reduced tree height (Leakey 1999). Okafor (1997) lists the desirable characteristics of *I. gabonensis* and *I. wombolu* from Okafor (1990) as follows:

- Fruit size.
- Fruit yield.
- Flavour.
- Lack of fibrousness.
- Short time to reproductive maturity.
- Wide range of products.
- High quality and value.

Leakey (1999) notes that as well as identifying the traits relevant to farmers, it is also important to consider qualities that are advantageous for specific products in the food industry, or indeed for other applications. It should be noted that farmer's presumptions about attributes are not always correct. Leakey *et al.* (in press) discovered that, contrary to the predictions of farmers, fruit weight and size do not correlate with kernel weight and size. Hence careful studies of the relationships between different traits are necessary to ensure that the characters that are used for selection will result in superior individuals. Leakey and his team have recommended several qualitative characters for use in the assessment of genetic variation in the fruit and kernels of *I. gabonensis* and have defined these as the 'ideotypes' for the production of fresh fruits and kernels (Table 8).

They consider that separate 'fruit' and 'kernel' ideotypes are useful to enable trees to be identified that produce either fruits for consumption or for kernel extraction. Additionally, subdivision of the kernel ideotype could distinguish oil-rich kernels for vegetable oil production from kernels suitable for cooking. In their study, they found that in a small sample of *I. gabonensis* trees from Cameroon, there were individuals that tended towards either the fruit or kernel ideotype, so their conclusion is that ideotype selection is possible for this species and would be beneficial to the domestication process.

Fruit Ideotype	Kernel Ideotype
High values for: • Flesh depth • Fruit weight • Good taste • Low fibrosity	*High values for:* • Kernel weight • Shell brittleness • Drawability

Table 8: Fruit and Kernel Ideotype characters for *I. gabonensis*. Source: Leakey *et al.* (in press).

One trait in particular could have a huge impact on the ease of extracting bush mango kernels. Ladipo *et al.* (1996) report the finding of a tree in Northern Gabon which has self-cracking seeds, resulting from unusually early splitting of the tough endocarp, which would normally happen later during germination. The kernels of these seeds can be extracted much more easily than from regular seeds, reducing considerably the labour required for kernel processing (Tchoundjeu *et al.* 1997). However, these self-cracking seeds have only been documented twice and therefore appear to be rare (Leakey 1999). Nonetheless, if this trait could be bred into trees for cultivation, it would have enormous benefits for farmers.

8 CURRENT ISSUES

8.1 Species and Habitat Vulnerability

At present, *I. gabonensis* and *I. wombolu* are widespread in West and Central Africa and would not be considered to be endangered species. Bush mango is maintained on tree and field crop farmland (Ayuk *et al.* 1999), and due to its valuable produce is unlikely to be cleared from this niche. However, the natural habitat for *Irvingia* spp., humid lowland forest, is being cleared for agricultural land and its products are often over-exploited. If wild *Irvingia* trees are lost, this will put an even greater strain on the limited produce of cultivated trees. In addition, potentially valuable genotypes could be lost and an important source of seedlings would be depleted (Ladipo *et al.* 1996). So, although the bush mango itself is not greatly threatened, its habitat needs to be protected to preserve the genetic variation in the two species and to prevent the trees from becoming endangered.

8.2 Possible Government Action

There are several ways in which West and Central African governments can act to promote the development of *Irvingia* production and markets (Agbor 1994):

- Introduction of policies for guaranteed minimum producer prices and the purchase of surpluses to provide an incentive for farmers to increase productivity.
- Development of road, water and storage systems to improve the infrastructure for production and trade.
- Funding of research into all relevant aspects of *Irvingia* spp., particularly those that are currently poorly understood.

- Distribution of knowledge about *Irvingia* spp. to farmers, with emphasis on the importance of these species.
- Establishment of *Irvingia* Farmers Associations (IFA) and Minor Crops Marketing Boards, as suggested by Ladipo *et al*. (1997), to increase the promotional possibilities for *Irvingia* products, both in Africa and to other continents.

8.3 Current Work on *Irvingia* Species

Recently, dispersed knowledge about *I. gabonensis* and *I. wombolu* has begun to be drawn together in reports such as this one to enable information to be easily accessed and so that gaps in the current knowledge can be identified. The proceedings of the ICRAF-IITA (International Institute of Tropical Agriculture) Conference on *I. gabonensis* in Ibidan, Nigeria that took place in May 1994 are due to be published, edited by D. Boland and D. Ladipo. ICRAF and similar organisations recognise the potential of *Irvingia* and are undertaking further studies of the species. The latest initiative is a FRP (Forestry Research Programme) funded project concentrating on *Irvingia* species and Dacryodes edulis, involving the collaboration of ITE (Institute of Terrestrial Ecology), ODI (Overseas Development Institute), C&CFRA and ICRAF/IRAD.

There are several researchers working in different areas on *Irvingia* species:

- R. Leakey at ITE in Edinburgh is continuing studies of the phenotypic variations of fruits and kernels, with a view to examining the genetic basis of the characteristics and the effect that domestication is likely to have on these species.
- D. Ladipo has recently published a paper on the quality control of bush mango.
- Lowe and colleagues are further investigating the molecular ecology of *I. gabonensis* and *I. wombolu* in the molecular lab at of the tropical section at ITE. They are assessing the genetic diversity of these species.

8.4 Gaps in the Knowledge at Present

One major areas which currently lacks in information is the trade of *Irvingia* products. There are few statistics available to quantify the volume and value of trade either locally, regionally or internationally. Clearly, it is important that studies to improve our understanding of the *Irvingia* markets are carried out (Ayuk *et al*. 1999), particularly so that the marketing potentials of new or presently under-exploited products can be quantified.

Some aspects of the biology of *I. gabonensis* and *I. wombolu* have not yet been fully described - for example the mating systems and other details of the reproductive ecology.

The extent of genetic variation both within and between *Irvingia* populations has not been fully assessed, although studies have begun (Leakey *et al.* in press). It is critical that the current genetic studies are continues to identify the patterns and potential of genetic variation.

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11 APPENDIX A

Botanical Descriptions of *Irvingia gabonensis* and *I. wombolu*

Irvingia gabonensis

Tree 10-40m tall; buttresses to 3m high; straight and unbranched (in wild trees); crown approximately spherical or taller than wide; foliage dense and dark green.

Leaves elliptic; apex tapering or occasionally with a barely discernible acute acumen; base acute to cuneate; length 4.5-8 cm, width 2-4 cm (canopy leaves from mature wild trees); secondary, tertiary and quaternary venation obvious, areolae greater than 1mm diameter.

Inflorescence axillary, laxly branched panicle to 9 cm long.

Flowers in fascicles; pedicels to 5 mm long; sepals 1-1.5 mm; petals yellowish white; 3-4 mm long; filaments 4-5 mm long.

Fruit ellipsoid to cylindrical, occasionally almost spherical, only slightly laterally compressed; length 4-6.5 cm, width 4.2-6.4 cm, thickness 3.4-6 cm; smooth; green when ripe; mesocarp bright orange, soft and juicy when ripe with a few weak fibres, fibres appressed and curly, or absent on old pyrenes; taste of mesocarp from sweet to slightly bitter with a turpentine flavour but always edible; pyrene single, woody but usually disintegrating after one season on the ground.

Seeds 2.5-3.8 cm long, 1.7-2.7 cm wide, 0.8-1.2 cm think; endosperm visible on fresh material as a white dot 2-3 mm diameter on the inside of the testa opposite the point of attachment of the two cotyledons, this sometimes extends to form a white streak 1-2 mm broad, running parallel to the axis of each cotyledon, on the inside of the testa.

Seedlings with purple to red cotyledons, hypocotyl and stipules; first pair of leaves opposite and stem pale green to purple.

Irvingia wombolu

Tree to 25m tall; buttresses to 2m high; bole often slightly leaning; first branch usually at 7-10m, foliage regular, not as dense as *I. gabonensis*.

Leaves elliptic to obovate, at least some leaves distinctly obovate; apex rounded often with a barely distinct blunt acumen; base obtuse to acute, occasionally very shortly cuneate; length (6.5-)10.5-14(-18) cm, width 4-6(-8.5) cm; often drying blackish or greyish green; secondary, tertiary and quaternary venation obvious, areolae greater than 1mm diameter.

Inflorescence a laxly branched panicle, to 9 cm long, axillary and on older twigs.

Flowers crowded together at the end of the inflorescence branches or in fascicles; pedicels to 6mm long; sepals 1 mm; petals, whitish, 3-4 mm long; filaments 5 mm long; disc bright yellow, diameter 2-3 mm.

Fruit ellipsoid, only slightly compressed laterally; length 4.5-5.8 cm; width 4.5-5 cm, thickness 4.3-4.8 cm; green on falling, often turning bright yellow and then black as the mesocarp starts to rot; mesocarp soft and juicy when ripe, fibres more obvious than in *I. gabonensis* but not as numerous nor stiff as those of *I. excelsa*; mesocarp very bitter and completely inedible.

Seeds 3.5-5 cm long, 1.7-2.6 cm wide, 8-10 mm thick; endosperm barely visible on fresh material as a white to almost translucent layer less than 0.5 mm thick, covering most of the inside of each half of the testa, in a split open seed.