Useful Plants of Zimbabwe With Potential as Smallholder Crops

Towards the Development of a National Bioeconomy Strategy

A shortlist of 25 indigenous plant species with commercial potential in the food, beverage, health and beauty industries

ZIMBABWE

IAPRI

Food and Agriculture Organization of the United Nations

UKaid from the British people

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About LFSP: The Zimbabwe Livelihoods and Food Security Programme (LFSP), Agriculture Productivity and Nutrition Component (APN) is managed by the Food and Agriculture Organisation of the United Nations (FAO), with the aim of contribute to poverty reduction through increased incomes for a target 250,000 smallholder farming households. The programme is being implemented in four provinces covering 12 districts as follows: Mutasa, Mutare, and Makoni in Manicaland; Guruve, Bindura, Mazowe and Mt Darwin in Mashonaland Central; Kwekwe, Gokwe North, Gokwe South and Shurugwi in Midlands and Zvimba in Mashonaland West provinces. FAO is in partnership with three NGO consortia led by Practical Action, Welthungerhilfe and World Vision International, two Strategic Technical partners i.e. IAPRI for policy influence, HarvestPlus for biofortification, three Commercial Banks, 1 Wholesale Facility - the Zimbabwe Microfinance Fund (ZMF), 5 Microfinance Institutions (MFIs) and the USAID managed DCA Facility. To date the LFSP is funded for two phases to the tune of £72.4m.

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Section 1: Introduction and Background

Zimbabwe is blessed with an exceptional abundance of natural biodiversity. However, the potential contribution of biodiversity to the national economy has historically been largely ignored. Whilst the critical ecosystem services it provides, especially in terms of watershed protection, may have been recognised, along with its key role as a cornerstone of the country's tourism industry, few of the other economic opportunities from sustainable use of biodiversity have commanded any sustained policy attention. This is in spite of the very significant and rich body of traditional knowledge in Zimbabwe relating to the sustainable use of (especially plant) biodiversity.

This has perhaps been a result of the emphasis given to industrial models of large-scale commercial agriculture. Whilst these models may have served the country well in the past, changing climatic conditions are demanding a more environmentally sensitive approach to rural land use. With 60% of the country experiencing less than 650 mm of rainfall a year (Natural Regions IV and V), and the cycles of drought becoming ever more frequent, Zimbabwe cannot afford to ignore the potential opportunities from sustainable use of indigenous biodiversity (especially plants). Zimbabwe's indigenous plants are well-adapted to the prevailing soil and climatic conditions and better able to withstand the periodic cycles of drought than exotic plants. They also require less (if any) agro-chemicals and are more compatible with soil-conserving land husbandry techniques.

Meanwhile there has been growing global consumer interest in sustainably-produced indigenous natural plant products. Consumers increasingly seek out production systems that are more biodiversity-friendly than industrialised agriculture. They also perceive greater health benefits from natural products, as well as reduced exposure to harmful agro-chemicals (as evidenced in the global growth in demand for organic produce). And, as a bonus, they value the enhanced social impacts associated with buying from self-employed harvesters as opposed to wage labourers on commercial farms.

Globally these trends have given rise to the notion of the "Bioeconomy", defined as the sustainable production and conversion of renewable biological resources into a range of value-added, bio-based products. Many observers see the bioeconomy as the next frontier of economic innovation globally, and several African countries have developed national and/or regional bioeconomy strategies (e.g. South Africa, Nigeria, the East African Economic Community). The bioeconomy is viewed as an alternative economic model to the present fossil-dependent model which is based in high consumption of non-renewable materials, with often low economic returns and extensive consumption of labour and natural resources.

Whilst there have been some scattered initiatives within Zimbabwe, stretching back for more than two decades, there has never been a formal policy to promote the development of the national bioeconomy. This report aims to change that by stimulating debate around the opportunities for Zimbabwe from the bioeconomy. The report identifies 25 indigenous plant species (from an initial long-list of 75 species) that have the potential to be developed as smallholder crops. These are plants with a history of traditional use, and for which commercial opportunities exist in the food, beverage, health and/or beauty sectors.

The primary rationale for developing these being that they generate better and more environmentally sustainable financial returns for smallholders, especially those living in the dryland areas of Natural Regions IV and V. The report then goes on to discuss the potential for indigenous plants to contribute to the growth of the Zimbabwean agricultural sector and to look at broader opportunities for the development of a national bioeconomy strategy.

This report is prepared as a policy research initiative under the auspices of the UK Government-supported LFSP-APN, which aims to contribute to poverty reduction through increased incomes for a minimum number of 200,000 beneficiaries' households.

Section 2: Description of the Methodology Used

2.1 Study Objectives

There are nearly 6,000 indigenous plant species found in Zimbabwe. Of these, at least 15% (900 species) are traditionally used as food or medicinal plants. However, less than 1% have made it through to commercial use, and smallholder agriculture is currently dominated by a very small range of predominantly exotic crops.

The objectives of the study are:

i. To develop a long list of 75 indigenous Zimbabwean plants that have historically been used as food and beverage, medicines or cosmetic ingredients, and that have significant potential to be incorporated into a newly revitalised Zimbabwean agricultural production system.
ii. In consultation with relevant stakeholders, to narrow this down to a short list of not more than 25 different plant species, each one of which could be sustainably harvested and/or cultivated for the benefit of rural people.
iii. To describe and photograph each one of these 25 species, outlining the key uses and potential livelihood opportunities.
iv. To summarise this information in a policy advocacy document that will be used to draw the attention of policy-makers and technocrats to the multiple potential opportunities from the commercial development of selected indigenous plant species.

Once completed, the information generated will then be available for a variety of applications, including information posters, videos, booklets, podcasts etc, all aimed at raising awareness about the potential uses of these plants.

2.2 Methodology

2.2.1 The Long List

The selection of the long list was based on the following critical characteristics.

Criteria for Species Selection for Long List

Each plant identified for the long list must:

- Be a plant whose ecology and management is broadly understood and is not considered to be under threat of over-harvesting;
- Occur in relative abundance and potentially significant quantities in Communal Areas in at least 5 different Districts in Zimbabwe;
- Have a history of safe traditional use;
- Have known product types with known markets;
- Be accessible to communities with some skills in ecological management, technical production and marketing; and
- Have relatively rapid development prospects, to deliver cash benefits to producer communities in a reasonable time.

2.2.2 The Shortlisting Process

Having identified the long list, a rigorous process of comparative analysis was undertaken to develop the shortlist. This process is adapted from the FAO's Market Analysis and Development (MA&D) guidelines. These guidelines were originally developed to facilitate the selection by rural communities of so-called Non-Timber Forest Products as a basis for developing successful enterprises (http://www.fao.org/3/a-x7451e.pdf). They were further refined by the UNCTAD BioTrade Initiative (https://unctad.org/en/Pages/DITC/Trade-and-Environment/BioTrade/BT-Initiative-Linking-programme.aspx).

The MA&D guidelines have, at their core, a matrix of questions, allied to a scoring system. The matrix is poses questions in four main areas of importance to product selection. These categories and the broad question they are intended to address are:

- Marketing: will the product sell if it is produced?
- Ecological: can the product be produced in an ecologically sustainable manner?
- Socio-economic: will this product bring meaningful benefits to low-income rural producers?
- Technological: are the technologies required to produce this product appropriate and accessible to rural producers?

The scale used to score each product was High, Moderate or Low. The scores are 3 for High, 2 for Moderate and 1 for Low. The scoring system gives more weight to marketing (maximum 30 points) than to the other three (maximum 18 points each).

Each product can therefore receive a theoretical maximum of 84 points. Various different products were scored independently, scores were then compared and the products were ranked in relation to each other.

The full scoring matrix used for this exercise is attached as Annex 1.

2.3 Results

2.3.1 The Long List

The long list of 79 species (75 from the original selection and a further 4 added as a result of inputs from key informants), that best meet the criteria outlined in section 2.2.1 was developed and is attached as Annex 2.

This was a challenging process, and was necessarily subjective (since the author could not obviously put all 6,000 indigenous plant species found in Zimbabwe through the species selection matrix). However, the final output represents the author's best attempt and was based on available knowledge and experience both of the Zimbabwean context and current global market trends. Furthermore it was reviewed and added to by a set of key informants, and then further reviewed and adopted at a stakeholder meeting in December 2020.

Of the long list of plant species:

- 3 are Climbers;
- 2 are Creepers;
- 18 are Herbs;
- 13 are Shrubs;
- 43 are Trees;
- 58 species are drought tolerant (i.e. able to survive in annual rainfall of less than 600 mm);
- 21 species require higher than 600 mm annual rainfall to survive and grow;
- 26 species are already cultivated;
- 33 species are currently wild-harvested but have the potential to be cultivated; and
- 20 species are currently wild-harvested and could not easily be cultivated.

Not surprisingly, many of these species produce multiple products of commercial potential. So, for example, the baobab tree provides a fruit powder that can be used as a food or a beverage, a seed oil that is a cosmetic ingredient, and a bark that has medicinal properties. Superficially, a plant capable of supplying multiple products into multiple market niches would appear to be more attractive than one with only a single product (e.g. Makoni tea, which is a herbal tea but not useful for much else). However, the reality is that commercial success will depend very much on how each product stands up to the competition in these different niches. The author therefore considered only one of the commercial product opportunities from each species, being the one most likely to attain (or already attaining) commercial success within the shortest timeframe.

Using the length of time to attain commercial success as a key criterion for product selection inevitably favours certain types of plant over others. This is because the regulatory barriers to commercialisation vary between different product categories. The regulatory requirements for licencing a new cosmetic product, whose sole objective is to enhance the appearance of the user, is limited to a basic toxicological and allergenic assessment of an externally applied product. A new food product, which will be internally ingested, naturally requires a more thorough safety assessment. New pharmaceutical/medicinal products need not only to prove their safety (itself a complex issue especially in terms of potential interactions with other pharmaceutical products), but also their efficacy, which can take years and millions of dollars to demonstrate. Typically therefore the products that can be used as cosmetics or food/beverages have shorter lead times to commercialisation than medicinal/Pharmacuetical products (unless, as in the case with e.g. Harpagophytum zeyherii, they are products already licenced for sale as a pharmaceutical ingredient).

2.3.2 Ranking

After detailed literature review and rigorous analysis, each of the selected species was put through the scoring process to give a final ranking as below. This was then shared with a group of key informants and presented to a stakeholder meeting, after which revisions were made. Although still prone to subjective assessments, every effort was made to ensure that the process was as objective and evidence-based as possible. It was a time-consuming and intensive effort, but the results are considered to be robust and comprehensive. Ultimately the higher scoring attributed to market factors was what swung the scoring in favour of certain species. Both local and export market opportunities were considered.

Rank	Species	Score
1.	Sclerocarya birrea	77
2.	Adansonia digitata	73
3.	Citrullus lanatus	71
4.	Harpagophytum zeyherii	71
5.	Schinziophyton rautanenii	70
6.	Trichilia emetica	69
7.	Ximenia caffra	69
8.	Parinari curatellifolia	68
9.	Cucumis metuliferus	65
10.	Ziziphus mauritiana	65
11.	Myrothamnus flabellifolia	64
12.	Vigna unguiculata	64
13.	Uapaca kirkiana	63
14.	Oryza glaberrima	63
15.	Cyperus esculentus	62
16.	Hyphaene spp	61
17.	Fadogia ancylantha	60
18.	Lippia javanica	60
19.	Vigna subterranea	60
20.	Cenchrus americanus	60
21.	Eleusine coracana	59
22.	Cleome gynandra	59
23.	Plectranthus esculentus	58
24.	Artemesia afra	57
25.	Aloe excelsa	57
26.	Calodendrum capense	56
27.	Bulbine latifolia	56
28.	Garcinia livingstonei	56
29.	Balanites aegyptiaca	55
30.	Centella asiatica	54
31.	Tylosema fassoglense	52
32.	Azanza garckeana	51
33.	Syzigium cordatum	50
34.	Dioscorea bulbifera	45
35.	Sorghum bicolor	47
36.	Croton gratissimus	44
37.	Amaranthus hybridus	43
38.	Withania somnifera	43
39.	Dovyalis caffra	43
40.	Coffea racemosa	43
41.	Faidherbia albida	42
42.	Vitex payos	40
43.	Lagenaria siceraria	40
44.	Erythrina abyssinca	40
45.	Diospyros mespiliformis	40
46.	Berchemia discolor	40
47.	Cassia abbreviata	39
48.	Ficus sycomorus	39
49.	Flacourtia indica	38
50.	Kigelia africana	38
51.	Elephantorrhiza elephantina	38
52.	Heteropyxis natalensis	38
53.	Olea europaea subsp cuspidata	37
54.	Bobgunnisa madagascariesnis	37
55.	Annona senegalensis	37
56.	Peltophorum africanum	37
57.	Ocimum africanum	37
58.	Lannea edulis	35
59.	Mimusops zeyheri	34
60.	Ficus sur	34
61.	Strychnos spinosa	34
62.	Vachellia karroo	34
63.	Piliostigma thoningii	33
64.	Terminalia sericea	33
65.	Corchorus olitorius	33
66.	Vangueria infausta	32
67.	Vachellia erioloba	30
68.	Strophanthus kombe	30
69.	Catharanthus roseus	30
70.	Hypoxis hemerocallidea	29
71.	Sansevieria hyacinthoides	29
72.	Vernonia amygdalina	29
73.	Warburgia salutaris	29
74.	Salvadora persica	29
75.	Prunus africana	29
76.	Rauvolfia caffra	28
77.	Tarconanthus camphoratus	28
78.	Helichrysum nudifolium	28
79.	Gloriosa superba	27

The ranking was completed using the matrix and the 25 highest-ranked species were shortlisted. Of these:

- 1 is a Climber, 2 are Creepers, 8 are Herbs, 4 are Shrubs, 10 are Trees
- 20 species are drought tolerant (i.e. able to survive in annual rainfall of less than 600 mm)
- 5 species require higher than 600 mm annual rainfall to survive and grow
- 11 species are already cultivated
- 8 species are currently wild-harvested but have the potential to be cultivated
- 6 species are currently wild-harvested and could not easily be cultivated.

A more detailed summary of the shortlisted species is included as Annex 3.

	Latin	English	Shona	Ndebele	Potential market
1	*Adansonia digitata*	Baobab	Muuyu	Umkhono	Superfood ingredient, cosmetic oil (skin), herbal tea
2	*Aloe excelsa*	Zimbabwe tree aloe	Chikohwa, Gavakava	Imangani	Cosmetics, skincare, herbal medicine, anti-diabetic
3	*Artemesia afra*	African wormwood			Herbal medicine, essential oil
4	*Cenchrus americanus*	Pearl millet	Mhunga	Inyawuthi	Staple grain, novelty export grain, brewing
5	*Citrullus lanatus*	Kalahari melon	Mashamba	Amajodo	Cosmetic oil (skin), edible seeds, herbal medicine
6	*Cleome gynandra*	Spider plant, spider-wisp	Nyevhe	Ulude	Health food
7	*Cucumis metuliferus*	Horned cucumber	Magaka	Umhlagahlaga	Food/beverage ingredient, herbal medicine, industrial use
8	*Cyperus esculentus*	Tiger nut, yellow nutsedge	Pfende	Inqodi	Food/beverage ingredient, bio-fuel, edible oil
9	*Eleusine coracana*	Finger millet,	Rapoko, Zviyo	Uphoko	Staple grain, novelty export grain, brewing
10	*Fadogia ancylantha*	Makoni tea	Musvisvinwa		Herbal tea, herbal medicine
11	*Harpagophytum zeyherii*	Devil's claw, grapple		Inkunzane enkulu	Herbal medicine, skincare, veterinary medicine, pet care
12	*Hyphaene petersiana*	Ilala palm	Murara	Ilala	Craft spirits, basketry, green packaging
13	*Lippia javanica*	Fever tea	Zumbani	Umsuzwane	Herbal tea, herbal medicine, essential oil, insecticide
14	*Myrothamnus flabellifoliius*	Resurrection bush	Mufandichimuka	Umafavuke	Herbal tea, essential oils,
15	*Oryza glaberrima*	African rice	Mupunga	Ingqoloyi	Staple food, novelty food,
16	*Parinari curatellifolia*	Mobola plum	Muhacha, Muchakata	Umkuna	Beverage ingredient, edible nut, cosmetic oil (skin)
17	*Plectranthus esculentus*	Livingstone potato,	Tsenza	Umbondiwe	Staple food, novelty food,
18	*Schinziophyton rautanenii*	Manketti, Mongongo,	Mungongoma	Umngoma	Cosmetic oil (skin and hair), edible nut
19	*Sclerocarya birrea*	Marula	Mupfura, Mutsomo	Umganu	Cosmetic oil (skin), beverage ingredient, edible oil, but
20	*Trichilia emetica*	Natal mahogany,	Muchichiri		Cosmetic oil (skin), soap ingredient, biofuel, insecticide
21	*Uapaca kirkiana*	Wild loquat, Mahobohobo,	Muzhanje	Umhobohobo	Fresh fruit, jam, syrup, beverage ingredient
22	*Vigna subterranea*	Nyimo bean, bambara nut,	Nyimo	Imdlubu	Staple food, novelty food, bean flour
23	*Vigna unguiculata*	Cow pea,	Nyemba	Indumba	Staple food, novelty food, bean flour
24	*Ximenia caffra*	Ximenia	Munhengeni	Umthunduluka	Cosmetic oil (skin and hair), cosmetic ingredient,
25	*Ziziphus mauritiana*	Jujube,	Musau		Food and beverage ingredient, craft spirits

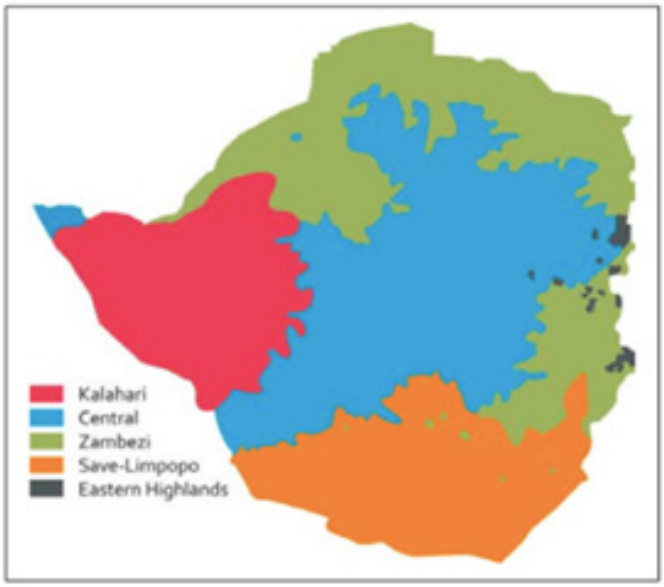
Perhaps not surprisingly, almost all of the short-listed species are ones for which there are already well-developed existing markets and market opportunities.

Section 3: Description of four main geographical regions of the country

In order to ensure full coverage of all of the marginal dryland Communal Areas of Zimbabwe, it is proposed that the country be divided into different geographical regions. Initially the option was discussed of simply using points of the compass (north, south, east and west). However, a more logical approach would be to use the eco-regions as identified in the Government of Zimbabwe's national biodiversity reporting. These are as follows:

Eco-region	% of total surface area	Corre-sponding Natural Region	Altitude	Meanannual rainfall	Dominant vegetation type
Kalahari	15	IV and V	1,030 m	560 mm	Colophospermum mopane, Baikiaea spp.
Central	38	II and III	1,300 m	620 mm	Brachystegia spiciformis, Julbernardia globiflora
Zambezi	26	IV	1,080 m	650 mm	Colophospermum mopane
Save-Limpopo	20	IV and V	687 m	400 mm	Colophospermum mopane, Acacia spp.
Eastern Highlands	1	I	1,500 m	740 mm	Grassland – Themeda, Exotheca, Loudetia Woodland – Brachystegia spiciformis, Julbernardia globiflora

Figure 1: Eco-regions of Zimbabwe



In order to ensure representation of all the dryland areas in the country, it is therefore proposed that at least 5 of the short-listed species are found in each of the following eco-regions:

- Kalahari
- Central
- Zambezi
- Save-Limpopo

Given that the Eastern Highlands is such a small area, and is dominated by private rather than Communal land, this eco-region was not specifically targeted (although species found in this region were not excluded).

Section 4: Description of each of the short listed species

4.1 Adansonia Digitata

Latin: *Adansonia digitata*
Family: Bombacaceae
English: Baobab
Shona: Muuyu
Ndebele: Umkhomo
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo.

Botanical Description

Adansonia digitata is one of Africa's most instantly recognizable and iconic tree species. It is a massive, deciduous tree which grows up to a height of 20-30 m tall and a diameter of as much as 20 m at adult age. The bark is smooth, reddish brown to grey, soft and possesses longitudinal fibres. The tree is highly branched and produces an extensive lateral root system which extends up to 80 m or more distant from the tree. The root tips are often in the form of tubers, but the main roots of old trees are relatively shallow and rarely extend beyond 2 m depth. The digitate leaves are alternate and leaflets are oblong to ovate, with lower leaflets being the smallest and terminal leaflet the largest. The leaflets are dark green, with short, soft hairs and looping lateral veins. Leaves of young trees are usually simple (making identification of young saplings difficult in the field). Adult trees begin each season by producing simple leaves followed by compound leaves with 2-3-leaflet. Mature leaves with 5 leaflets (20 cm diameter) only appear later.

The inflorescence consists of a single flower, situated in the axils of leaves near the tips of reproductive branches. The flowers are waxy white, large, solitary or paired in the leaf axils, and showy. They reach up to 20 cm in diameter, with a deeply lobed calyx with white, silky hairs inside and large, crinkly, spreading petals. The petals bruise easily and become brown, and the flowers have an unpleasant scent. Flowering begins at the end of dry season or just before the first rains, often when the first leaves appear. The flowers open in late afternoon and fall the next day at dawn. The hard, woody-shelled fruit are ovoid, 12 cm or more in length, covered with greenish-yellow velvety hairs. The seeds are smooth, embedded in a whitish powdery pulp, and have little or no endosperm.

Adansonia digitata occurs naturally in most of sub-Saharan Africa as a scattered tree in the savannah, and is also present in human habitation. Being essentially succulent in its physiology, the tree survives in very dry areas. In Zimbabwe it is found at altitudes of below 900 m in four ecological regions of the country.

Traditional Uses

Few African trees have as many and as diverse a range of traditional uses as the baobab. Revered across the continent for its immense stature and age (baobab trees can live up to 2,500 years old), the tree plays an important part in cultural and spiritual rites and ceremonies wherever it is found. All parts of the tree are used by humans in some form or other and researchers have documented over 300 known ethnobotanic uses to date (Kozanayi, 2014).

The most commonly consumed part of *A. digitata* is the powdery fruit pulp which is eaten raw, added to porridge or mixed with water or milk to make a juice. In Senegal the national drink "bouye" is a blend of baobab, milk and sugar, consumed almost daily by people across the country. The fermented juice is often used to make a traditional beer, and the powdered pulp is sometimes added to beer as a fermenting agent. There are many health benefits and medicinal uses associated with the fruit pulp.

The most widespread is simply as a health tonic to improve overall strength and immunity, but it is also frequently taken as a treatment for diarrhoea, coughs, colds and influenza. Athletes drink a mixture of baobab powder and water to give them strength and endurance, and the same beverage is also of-

ten taken to help prevent the onset of diabetes and other metabolic diseases, and to treat hypertension.

The leaves of *A. digitata* are a staple food for many populations in Africa, especially the central region of the continent. They are usually harvested in great abundance and are sun dried for use in the dry season. The dried leaves can either be stored as whole leaves or pounded into a fine powder. Young leaves are widely used, cooked as spinach when fresh or added to sauces, porridges, thick gruels of grains and boiled rice when in dry powder form. The young leaves also provide fodder for game and domestic animals (often to the detriment of young saplings in the wild). Smoke from the leaves is known to be an insect repellent (Lisao *et al.,* 2017).

The bark produces a good quality fibre which is used to make ropes and traditional mats. In Zimbabwe this is so common in the south-east of the country that almost every tree has been harvested as a source of the fibre and the resultant products are called "Chipinge rugs" for their unique design and unusual raw material. The bark also has many traditional medicinal uses, with decoctions being used to treat pain and inflammation. The roots also have medicinal use and are boiled in water and taken as a cough remedy.

Other uses of baobab include as a source of oil from the seeds (used for both cooking and skincare), edible seeds consumed as a nut or roasted and ground into a coffee substitute, the wooden shells are used as firewood, and the seedcake makes an excellent stockfeed. The tree is also important in apiculture as it is a source of fine quality honey. In many parts of Africa, the hollow trunks are used for beekeeping.

Commercial History

The commercial history of baobab in Zimbabwe dates back to the mid 1990s when the NGO SAFIRE first began working with baobab-harvesting communities in Rushinga to produce a seed oil for sale into the cosmetic market. Later efforts began to focus more on the fruit powder. In 2001, the Harare-based trade association PhytoTrade Africa (of which SAFIRE was a founding member) took on baobab as one of its focal species. Again the initial focus was on the oil for cosmetic markets (on the basis that the regulatory obstacles for market access are lower for cosmetic use than for food use). In 2004 PhytoTrade began work on submitting an application to have the fruit pulp certified as safe for human consumption in the EU under the Novel Foods regulations. It took 4 years for this application to be prepared, submitted and approved, but in July 2008 baobab was given the green light for marketing in the EU, and this was followed a few months later by FDA approval for sale in the US.

Since the EU Novel Foods approval, the baobab industry has grown substantially in many countries across Africa. Today at least 600 tonnes of baobab powder are exported from Africa per year, mostly to Europe and North America. Zimbabwe is one of the largest producers in Africa, with several companies involved in the production and processing of baobab powder and baobab oil. The majority of production from Zimbabwe is certified organic, and Africa's only baobab powder to be certified under the Fair Wild scheme also comes from Zimbabwe.

There has also been a considerable degree of value addition around baobab in Zimbabwe. Finished products manufactured and marketed locally include juices, jams, pre-cooked porridges, hair and skin care products, craft beer and a variety of snacks and confectionaries. Unprocessed fruits are traded informally on roadsides and in fresh produce markets. Rural people use the pulp to make ice lollies ("freezits"), which are traded on informal, mostly urban markets. The press cake is sold as a stockfeed, and the fruit shells are composted and marketed as an organic fertiliser.

Potential Commercial Uses

The fruit is an ideal candidate for the functional food industry and has justifiably earned the title of the "African superfruit". With very high levels of vitamin C, fibre, calcium, potassium, magnesium and phosphorus, the nutritional profile of baobab compares favourably with any other superfood, and there are many potential applications for superfoods in the food and beverage industries. The biggest single category of use at present is simply as a raw superfood powder. Consumers buy baobab powder for home consumption, either mixing it in with other dishes, combining it with fruit to make a smoothie or adding water to it to make a drink. It is also being bought by food and beverage manufacturers as an ingredient in a wide range of products including smoothies, fruit juices, cereals, granola bars, yogurts, snacks, confectionary and baked goods.

New categories for future product development include sports nutrition, diabetic-friendly, vegan, non-dairy, paleo and probiotic food and beverages. Baobab powder also has certain functional attributes, serving as a thickener, an acidifier, a natural preservative, a yeast substitute and a flavour enhancing agent. All of these suggest potential industrial applications in the food industry, and this is becoming the focus of more intense research now.

The seed oil is already marketed as a cold-pressed oil for use in the cosmetics industry. Its particular attributes include a high degree of moisturising action (preventing Trans Epidermal Water Loss) as well as providing an array of important nutrients for the skin, including high levels of Omega 6 and 9 fatty acids and naturally antioxidant phytosterols. The oil is either bought in its pure form by consumers for topical application on their skin, or is used by cosmetic manufacturers as an ingredient in skin and hair care formulations. There is substantial scope for further new product development in the cosmetic and personal care sectors, and this is expected to be a major growth area in the coming years.

A third potential commercial use of baobab is as a herbal tea. The fruit powder, the leaves and the fibrous red funicle that binds the seeds and the powder together all have attributes that would make them good herbal tea ingredients. This has been only partly explored so far, but shows very promising signs for the future.

Other potential products from baobab include leaf extracts for cosmetic and medicinal use, herbal remedies based around the fruit pulp, cosmetic scrubs using the seedcake, activated carbon from the shells and natural fibres from the bark, and the incorporation of the fruit powder and/or funicle as an ingredient in craft beers and craft spirits.

Market Potential

Baobab is the only ingredient native to Zimbabwe that is currently classed as a *"superfood"*. The superfood market is enormous. In 2018 it was valued at USD 137 billion/yr, and growing at 5.9% per annum (Grand View Research, 2019). The current global pandemic has accelerated this growth, with more and more consumers turning to healthy superfoods to help build and maintain immunity. Of the superfoods, the fruits are the biggest category and the North American market is the fastest-growing.

Baobab oil is already well-established in the global market for cosmetic oils, which is currently valued at over US$50 billion/yr (Grandsview Research, 2019). Key drivers of growth for baobab are a move by consumers away from using petroleum-based skincare products towards more natural alternatives and growing enthusiasm from millennial consumers for products with an ethical and traceable backstory. Whilst Europe will retain the prominent

value share in the global baobab oil market (mainly because it is home to many of the major cosmetic manufacturers), other markets are likely to see significant growth. Included in this are domestic and regional markets.

The third, and so far largely untapped, market for baobab products is the global herbal tea market which, like the superfood market, is booming, growing at 6% year on year and currently valued at over US$5 billion/yr (Allied Market Research, 2020). The scale of the Rooibos industry in South Africa gives an indication of how this market could grow for baobab. The herbal tea market has also been boosted by the global COVID-19 pandemic, with consumers around the world turning to herbal teas to help build immunity. Baobab fits well into this category, with its already established reputation as an immune booster.

Cultivation/ Domestication Potential

Adansonia digitata is a tree of high economic potential with a range of uses. Its ability to withstand drought will result in increase utilisation pressure on the baobab tree as other plant species fail to cope with predicted changes in climate (Sanchez *et al,* 2011). This necessitates investment in propagation.

Although slow-growing, baobabs propagate readily from seed. Optimal growth conditions are average day temperatures ranging from 19°C to 35°C, annual rainfall between 300 and 500 mm (Orwa *et al.,* 2009). Land preparation is done in the summer or at the onset of the rainy season to preserve the soil structure. Sandy, well-drained soils support seed germination and seedling establishment better than all the other soil types (Chia *et al.,* 2010). For seed propagation, seeds can be scarified mechanically by scarring the seed case with a knife and then soaking in hot water for 2-6 hrs to speed up the process of germination which should take 10 days. In-vitro micropropagation has also been successful in the past mainly for mass cultivation (Ndoye *et al.*, 2012). Vegetative propagation involves the growth of a new tree from a shoot, bud or cutting from a good-quality mature tree. Traditionally, trees have been propagated by transplanting naturally regenerated seedlings.

Seedlings are transplanted into the field at 10 m x 10 m spacing at a depth of 60 cm. Organic and mineral fertilisers can be used, however it is recommended to use farmyard manure, compost or green legume manures, especially at the time of planting for intensive leaf production. The amount of water required varies with the size of the tree and also depends on local climatic conditions. Generally, about 1-2 L of water should be applied twice a week to the base of each young tree. Mature baobab trees require no irrigation. Like any other tree, weeds should be removed from around the tree during the early stages of growth. There are no serious pests and diseases of baobab. However, some fungal and viral diseases have been recorded and several insects attack the wood, fruit and young shoots. These can be controlled using the integrated pest management approach (IPM).

4.2 Aloe excelsa

Latin: *Aloe excelsa*
Family: Liliaceae
English: Zimbabwe tree aloe
Shona: Chikohwa, Gavakava
Ndebele: Imangani
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save Limpopo, Eastern Highlands

Botanical Description

Aloe excelsa, commonly known as the 'Zimbabwe tree aloe', was named for its lavish growth amongst the ruins of Great Zimbabwe. It is found in warmer areas, amongst wooded grasslands and frequently on rocky outcrops or hillsides. It normally grows to a height between 3 and 6 metres, with a single central stem crowned with a large and succulent rosette at the top. The lowest part of the stem is typically swathed in the remains of dead leaves. Leaves are dark green, large, spreading and succulent, while the lower ones are conspicuously drooping. The leaves are often rosette with spiny toothed, reddish brown margins. Prickles are usually present on the lower leaf surface near the apex. These disappear as the plant grows and becomes less susceptible to browsing.

This species can be easily confused with *Aloe ferox* or *Aloe africana*, especially when they are fully grown. The flowers are distinguished by the fact that the racemes of *A. excelsa* are shorter and slightly curved. The flower heads are branched; each spike is densely flowered, orange to dark red in colour. The flowers are usually nodding, with a bright glossy red to orange-yellow perianth. The flowers develop from July to December and are a striking feature of the Zimbabwean landscape at this time. *A. excelsa* thrives in a variety of grasslands and woodlands mostly on rocky outcrops or hillsides. In Zimbabwe it is found across all ecological regions, predominantly in areas with rocky outcrops or on hillsides, and is one of 30 different aloe species in the country. *Aloe excelsa* is also found in several neighbouring countries.

Traditional Uses

The *Aloe excelsa* is known as *"inhlaba"* to traditional healers in Zimbabwe, who use several succulent plants together with other indigenous trees and plants in their medicines. They also believe there are male and female aloes, male plants having more spines on their leaves than female plants. The leaves, which are known to cure several aliments, are collected from the wild by traditional healers, dried and boiled to extract a decoction which then has a number of medicinal uses. These include being taken as an oral infusion for the treatment of abdominal pains, jaundice or to remedy a depressed fontanelle in infants. As a cure for asthma, the leaves are burned, mixed with salt and taken by mouth. The leaves are also used as an infusion in fowls' drinking water to cure fowl-pox.

A. excelsa has also been extensively used as a traditional remedy for topical skin conditions. The lectin content of *A. excelsa* is higher than in other aloe species. These lectins are responsible for the coagulating properties that make it an effective treatment for burns, cuts, scrapes and lacerations.

Other medicinal uses include as a cure for sexually transmitted diseases, spasms, ulcers and as a laxative (which use is common in other countries where this aloe is found). Finally, another traditional use by cattle herders is to suck the sweet nectar of the inflorescence for energy.

Commercial History

There are over 500 Aloe species worldwide, many of which are commercially traded either as live plants for the ornamental plant industry or as extracts for the cosmetic and medicinal plant industry. Of these the best-known is *Aloe vera,* whose annual market value is reportedly in excess of US$ 600 Million/yr in 2019 (IMARC., 2019). Closer to home, *Aloe ferox,* commonly known as the Cape Aloe, has a very long history of commercial use for pharmaceutical and cosmetic purposes, and is today one of South Africa's most heavily wild-harvested and commercially traded indigenous plants. The main commercial products of *A. ferox* are the leaf sap, used to make Aloe bitters, and the leaf gel used in skin care.

A. excelsa has not been widely used commercially, although it has found itself into some cosmetic formulations. In the 1990s in Zimbabwe, a local skincare brand produced a proprietary formulation blending *Kigelia africana* and *Aloe excelsa* extracts to combat sun damage to the skin (based on research by Maisiri and Gundidza 1999). However, much of its trade has been as an ornamental plant.

There are also significant (but unquantified) volumes of *A. excelsa* used by traditional healers and traded in medicinal plant markets.

Potential Commercial Uses

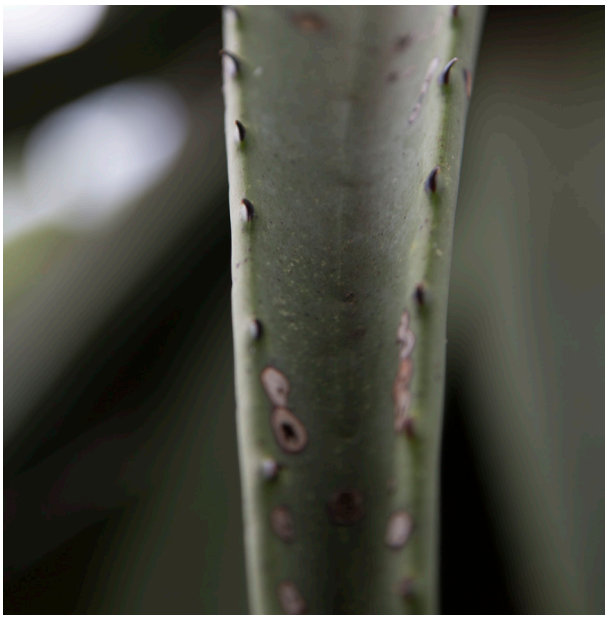
There are several different potential commercial uses for *Aloe excelsa*. Some of these are derived from the fact that *A. excelsa* exhibits traits similar to those found in other Aloe species. Others are more specific to the unique combination of compounds found in this plant.

Perhaps the first and most obvious potential commercial use is as a dermatological product. *A. excelsa* has potent antibacterial and antifungal activity (Coopoosamy and Magwa., 2007). This suggests efficacy in both wound-healing formulations and skincare. At the same time, the soothing effects of Aloe gel make it a desirable and effective ingredient in burn ointments, sunburn treatment and UV sun-protection formulations.

A second potential use, for which scientific validation already exists, is in the management and treatment of Type 2 Diabetes. Two phytochemicals isolated from the leaf extract have been shown to have potent antidiabetic activity (Coopoosamy and Magwa., 2006), and a leaf extract showed significant activity on reducing blood glucose levels in diabetic rats (Gundidza et al, 2005). This tallies with research work that is being done on a broader level on the use of Aloe extracts to help diabetic patients (Singh *et al* 2020).

A third potential use is in veterinary medicine as an anticoccidial. Coccidiosis is a common parasitic disease affecting poultry. Leaf sap of A. excelsa has been found to be effective in the treatment and prevention of coccidiosis, making it a potentially desirable and low-cost treatment suitable for poultry farmers (Gadzirai *et al.,* 2005).

A fourth potentially important commercial use for *A. excelsa* is as an ornamental plant. There is significant interest from global collectors and gardeners in different succulent plants, as long as the complexities of international trade in a CITES Appendix II listed plant can be managed.



Market Potential

The burgeoning global market for natural-ingredient based products has created robust demand for Aloe based products, especially from *A. vera* and *A. ferox*. This creates multiple opportunities for *A. excelsa,* which has notable and proven similarities to *A. ferox*.

Domestic consumers in Zimbabwe already purchase a wide range of products incorporating *A. vera* and *A. ferox*. These include personal care and toiletry products (Aloe gel, lotions, toothpaste, soap, shampoo, hair moisturiser), sun care products (sunscreen, after sun), skincare (moisturising and anti-ageing formulations) and wound healing/burn

treatment ointments. Although most of these products are imported (including a substantial volume of products from a British multi-level marketing company), many could readily be produced locally with consequent cost-savings and reduced requirements for scarce foreign currency.

Another area of considerable local interest would be as an antidiabetic ingredient in food and beverage products. There are already several products produced and sold locally that incorporate *A. vera,* including a yoghurt, an ice cream and various beverages. Substituting the *A. vera* with *A. excelsa* would be easy to do, and the growing numbers of Zimbabweans with Type 2 diabetes represent a significant market opportunity.

From an export point of view, it would take considerable effort to convince consumers and manufacturers that *A. excelsa* would be superior to either *A. vera* or *A. ferox*, both of which would undoubtedly be cheaper. However, there are compounds found in the Zimbabwean aloe that are unique, and further research could identify potential market niches that specifically apply to *A. excelsa.*

The USD 30 billion/yr export ornamental horticulture market is also worth further investigation. South Africa is the main supplier internationally of Aloes into the global market for horticultural trade, and there is no reason Zimbabwe should not also join this trade.

Cultivation/ Domestication Potential

All Aloe species are protected by the Convention on International Trade in Endangered Species (CITES), except for *A. vera* which is widely cultivated. It is therefore necessary to consider sustainable harvesting and commercial cultivation of the species.

A. excelsa can be successfully propagated. It prefers dry, tropical climates, open areas and full sun, in well-drained sandy loamy soils, with pH ranging from 7.0 to 8.5. Aloes in general require little or no soil preparation before planting. *A. excelsa* can be propagated from seed or vegetatively from the sideshoots that emerge close to the ground or from head cuttings. Plants are sown at 1 metre intervals. It takes about 4-5 years for the plants to reach the first harvest from the seed stage. At the time of harvest, each leaf weighs about 1.5-2 kg. Moderate water is required (once or twice a week), too much or too little will compromise the number and weight of leaves. Compost based manure is most effective to apply at a rate of 30-60t/ha and this could be split throughout the season. The older and outer leaves are harvested first leaving the younger leaves to grow. Aloe species are also effective agents for degraded rangeland treatment because of their mate-like root systems, which enhance soil binding.

4.3 Artemesia afra

Latin: *Artemisia afra*
Family: Asteraceae
English: African wormwood
Shona:
Ndebele:
Regions in Zimbabwe: Zambezi, Central, Save-Limpopo, Eastern Highlands

Botanical Description

Artemisia afra, 'African wormwood', is one of Africa's most significant medicinal plants. It is a multi-stemmed perennial shrub which grows up to 2 m in height. It is characterized by feathery leaves, with a pungent aromatic smell. The soft leaves are 6 cm long and 4 cm wide, alternately arranged and oval in shape. The upper surface of the almost fern-like leaves is dark green whereas the undersides and the stems are covered with small white hairs, which give the shrub the characteristic overall silver-grey colour. The inconspicuous flowers are pale yellow and borne at the ends of the branches. The cream-coloured flower heads are produced at the end of summer. In colder areas, the branches die back in winter and regenerate from the base (Graven *et al.,* 1992).

Artemisia afra grows in thick, bushy, slightly untidy clumps, usually with tall stems. The stems are thick and woody at the base, becoming thinner and softer towards the top. Many smaller side branches shoot from the main stems. The stems are ridged with strong swollen lines that run all the way up. Very typical of *A. afra* is the strong, sticky sweet smell that it exudes when touched or cut.

A. afra occurs throughout east and southern Africa. In Zimbabwe it is generally found in the east of the country, mostly on damp slopes, along stream banks and forest margins. It occurs in four of the country's ecological regions.

Traditional Uses

Artmesia afra is one of the best-known of all medicinal plants from Africa. With its intense and invigorating aroma, it is no surprise that the plant's most common use is as a remedy for common colds, coughs, sore throat, influenza, asthma as it is believed to clear the respiratory and bronchial passages (van Wyk *et al.,* 1997). The leaves are heated and the vapours inhaled to alleviate symptoms of colds and flu. Alternatively fresh leaves are inserted into the nostrils, especially to clear blocked nasal passages. It is also regularly used to treat fevers and malaria (like its more famous cousin *Artemesia annua).*

Another common set of medicinal uses are for gastro-intestinal disorders. Its English name "wormwood", applied to all members of the genus, relates to the widespread use of Artemesia spp to get rid of intestinal worms, and it is also used to treat indigestion, constipation and gastritis. The leaves are prepared as an infusion or decoction and consumed orally. It can also be applied topically to ease the pain or hasten bursting of boils, carbuncle and for other skin inflammations to rejuvenate the skin. Fresh tips are inserted into hollow teeth to treat toothache (Liu *et al.,* 2009).

Another interesting use of *A. afra* is in addressing gynaecological issues such as dysmenorrhea, amenorrhea and menstrual cramps. The genitals are steamed with vapours for menstrual chills and also after childbirth, while decoctions of leaves have been administered for extended labour (Patil *et al.,* 2011). Although medicinal use most commonly relates to the leaves, other plant parts such as the roots are also used as ingredients in various herbal preparations. The dry and fresh leaves together with the young stems are used to prepare infusions, decoctions, molasses and tinctures. The infusions are often made syrupy by the addition of sugar or honey to mask the bitter taste (Gwebu, 2003).

In South Africa, where it is commonly called by its Afrikaans name "wildeals", the plant is used to make a popular medicinal brandy, and has common use as an insect repellent, with sprigs being placed in wardrobes to keep moths away.

Commercial History

A. afra is closely related to the so called 'Chinese herb', *Artemisia annua* which contains artemisinin, the active ingredient in anti-malarial drugs (Liu *et al.,* 2009). These anti-malarial properties, together with other medicinal properties, have been explored and a variety of herbal remedies based on *A. afra* have been developed. South Africa has been the centre of its trade and commercial use in southern Africa. At one time there were several herbal medicine brands marketing *A. afra* products for prevention and treatment of malaria in South Africa. In 2013 it was banned by the South African Medicine Control Council on the basis that there was insufficient scientific evidence of its efficacy. It came to

prominence again in 2020 when the Malagasy government launched a herbal remedy for COVID-19 based on *A. annua*, prompting a resurgence of interest in the healing properties of *A. afra.*

The essential oil from *A. afra* was commercialised by a South African research team in the early 1990s and is still marketed internationally as an aromatherapy ingredient. It is particularly used as the basis for a steam inhalation.

There is little evidence of its commercial use in Zimbabwe, though, and despite being naturally found in many places in the country, there is no documented record of any vernacular Zimbabwean names for the plant.

Potential Commercial Uses

A. afra contains both a rich history of traditional medicinal use and a wide and complex range of secondary metabolites. Both of these factors point to commercial potential as a herbal medicine or for drug discovery, particularly as researchers have found little evidence of adverse toxicology. Note that the one compound not found in *A. afra* is artemisinin, the active ingredient in *A. annua.* However, that fact notwithstanding, researchers have found antimalarial activity in the plant's extracts, possibly attributed to the high arginine content. It has also been found to be a highly effective treatment of schistosomiasis (bilharzia) (Munyangi *et al.,* 2018).

One of the most commercially interesting and well-researched medicinal effects of *A. afra* is as a treatment for high blood pressure. Several compounds in the plant are linked to this, including scopoletin and arginine, as well as the unusually high levels of potassium. Ultimately it is believed that the efficacy derives from the synergistic effects of several of these compounds working together (Lutgen, 2019).

Another key potential medicinal use of *A. afra* is as a treatment for diabetes. Its hypoglycaemic effects are significant and it has been found to be more effective than many conventional drugs at decreasing blood glucose levels, while also having less side effects.

The aromatic and pharmaceutically active essential oil, made from the aerial parts of *A. afra,* have current and potential use in the food industry, perfumery, cosmetics and pharmaceutics. Interestingly there are significant variations in the phytochemical composition of essential oils from different parts of Africa. This could be a useful competitive edge for Zimbabwean producers if the Zimbabwean oil were found to have different chemical constituents.

Potential products incorporating the essential oil include health drinks/tonics, teas, alcoholic beverages, skin care products, hair care products and aromatherapy products. The volatile oil shows significant antimicrobial activity, as well as its strong insecticidal properties, and is an effective base for insecticides or insect repellents (Patil *et al.,* 2011). It can also be applied in organic farming practices as an organic insecticide.

Researchers also believe that *A. afra* is likely to contain important "prodrugs", based on the range of traditional medicinal uses it has and the fact that not all of these are attributable to compounds identified within the plan. Prodrugs are biologically inactive compounds that are metabolised in the body to produce a drug. This suggest much more research is needed on this plant.

Market Potential

A. afra has attracted attention globally due to its possible use for malaria, cancer, diabetes, hypertension and respiratory ailments (amongst others). Whilst pharmaceutical markets rarely create meaningful market opportunities for smallholder farmers (because of both the extremely high quality requirements for pharmaceutical raw materials and because of the need to standardise raw material to produce the desired compounds), the related herbal medicine opportunities can be significant.

The global herbal medicine market is large and rapidly growing. Currently estimated at USD 148 billion/yr in 2020, it is projected to reach USD 219 billion/yr by 2026 (Market Watch, 2021). *A. afra* already has an established reputation in Africa, and could do very well as a herbal remedy for malaria (nearly USD 1 billion/yr are spent on antimalarial medicines), diabetes (USD 70 billlion/yr in 2019) and hypertension (USD 25 billion/yr in 2019).

The essential oils market also has potential to absorb significant volumes of *A. afra* raw material. The global essential oils market size was estimated at US$7 Billion in 2019 and is expected to reach US$14.1 Billion by 2026 (Globe Newswire, 2020). There is also a small but growing local market for the essential oil, which is currently met from imported supplies from South Africa.

Cultivation/ Domestication Potential

Artemisia afra is clump-forming, and is common in highland areas at altitudes ranging between 1500 and 3000 m. The soils range from volcanic ash, loamy sands, to sandy or calcareous clay loams of volcanic or granite origin. *A. afra* can be propagated by cuttings (root or stem) or seed. Stem cuttings approximately 10 cm long, cut from the base of the stem, can be planted into a prepared seedbed and kept moist until well established. Use of semi-hardwood rooting hormone can quicken formation of roots in 4 to 6 weeks. Root cuttings also work well, however, only a limited quantity can be made from a single mother plant. Once a plantlet has a strong root system it can be planted out into the open field.

In terms of propagation by seed, seed collection from wild populations may produce plants that are diverse in both physical and chemical appearance. If varieties with specific properties are selected, it is recommended that vegetative propagation be done to keep these true to type (Patil *et al.,* 2011). Fresh seed germinates readily, but plants take longer to mature than from cuttings. It is necessary to keep the soil moist until germination takes places, which is usually between 2 to 8 weeks. Once seedlings are ready, they should be planted using an intra-row spacing of 30cm and interrow spacing of 60 cm, giving a plant population of 55 000 plants per hectare. Fertilizers can be applied in relation to soil test results but 3-5 t/ha of organic manure has worked in the past.

Irrigation is critical in the first three months until the plants reach maturity. No specific pests are known to attack *A. afra* because it is usually grown on a small scale, however natural pest control measures should be prioritised to control any potential pests. The leaves can be harvested any time. *Artemisia afra* is easily disseminated from the seeds, cuttings and rooted pieces and it grows well in the wild and in cultivation.

4.4 *Cenchrus americanus*

Latin: *Cenchrus americanus*
Family: Poaceae
English: Pearl millet
Shona: Mhunga
Ndebele: Inyawuthi
Regions in Zimbabwe: Zambezi, Central, Save-Limpopo, Kalahari

Botanical Description

Cenchrus americanus (synonym *Pennisetum glaucum*) is one of the oldest cereal crops of African origin, and is now grown around the world. It was first domesticated in Mali around 2500 BC and reached India shortly afterwards. Other common names include bullrush millet or candle millet.

Pearl millet is a very robust annual grass which tillers widely from the base and grows in tufts. It has slender stems which are also divided into distinct nodes. Pearl millet can reach 0.5 to 4 m in height depending on the cultivar. It has an extensive root system that renders it a drought tolerant crop. The leaves are linear or lance-like, possess small teeth and can grow up to 1 m in length. The ligule, or junction of leaf blade to leaf sheath, is a fringe of hairs 2-3 mm long. The sheath has very sparse hairs at the base of the collar and is often hairless. The inflorescence (flower) is a spike-like panicle, made up of many smaller spikelets where the grain is produced. The fruit (or caryopsis) is cylindrical, white or pearl in colour, or sometimes yellow or brown, and occasionally purple (Jennings *et al.,* 2010). It has the largest kernel of all the varieties of millet.

It is mostly adapted to areas which experience high temperatures and receive low rainfall. In Zimbabwe it occurs in four ecological regions.

Traditional Uses

As with the case of other small grains that are grown in Zimbabwe, *Cenchrus americanus* has been used mostly as food and a beverage. The grain is roasted and milled to make a flour which is used as an alternative to maize flour (Chandiposha *et al.,* 2013). The pearl millet flour is used to make a thin porridge which is served at breakfast. It can also be prepared into the traditional Zimbabwean staple porridge (*sadza*/*isitshwala*). When people such as children or hunters have to be away from home for long periods, ground pearl millet is mixed with peanut butter to make food balls called *modho,* which can last for days (Mukonyora, 1999). These are usually steamed and not baked. Another important use is as the base for beer brewed for specifical ritual events. It also makes a non-alcoholic beverage popularly known as *maheu*.

Globally, pearl millet is consumed primarily as a porridge, a flatbread or a fermented beverage (either alcoholic or non-alcoholic). In many of the drier parts of Africa (especially in the Sahel region from which it originally evolved), it is the only grain crop that can withstand the periodic cycles of drought. There are several traditional medicinal uses associated with the plant, including as a general tonic, to restore lost appetite, to treat chest disorders, leprosy and jaundice. The vapour from the boiled inflorescence is inhaled as a steam treatment for respiratory diseases (*Chopra et al.,* 1986). The plant stems can be used for roof thatch and building construction and the split stems are used in basketry.

Commercial History

Pearl millet is one of the most important cereal crops in Africa, ranking third behind maize and sorghum (Krishnan and Meera, 2018). However, it has always suffered from the perception that its productivity levels are much lower than other commercial grains and has consequently remained a largely subsistence crop. In Zimbabwe there is considerable resistance to the growing of pearl millet from farmers, attributed to a range of factors including the perceived higher labour costs of weeding, bird scaring, harvesting and grain processing compared to maize (UNDP, 2019). Other causes for the general maize preference include lack of technology, non-availability of fertilizers, poor market infrastructure in the small grains industry and inadequate investment in improved yields and varieties. There is also some cultural resistance, and in some areas of Zimbabwe pearl millet cultivation has been effectively banned because traditional leaders consider the crop brings bad luck (Mambondiyani, 2020).

Similar to sorghum, pearl millet has been brewed to produce alcoholic beverages in Africa. "*Uphutsu*" in Mozambique and "*Oyokpo*" in Nigeria are some examples of traditional alcoholic beers brewed from pearl millet. In India, the craft brewery, Great State Ale Works, produces a millet ale with 56% pearl millet (Smart Food, 2020), and recently craft brewers in Botswana, Zimbabwe and South Africa have been running trial productions of malted pearl millet beers. Although industrial processing of pearl millet meal in Zimbabwe has been relatively limited

(Phiri *et al.,* 2019), millet flour from small-scale millers has been sold in retail shops for several years. Small quantities of flour have also been used animal feed in Zimbabwe. Pearl millet has sometimes been successfully exported from Zimbabwe, mostly to Mozambique and South Africa (Selina Wamucii, 2020). In South Africa it is grown commercially mostly as a forage grass.

Potential Commercial Uses

Changing climatic conditions are altering growing conditions for many staple crops in Africa. Millets in general are considered 'climate change compliant crops' and they score highly over other grains like wheat and rice in terms of marginal growing conditions and high nutritional value (Kumar *et al.,* 2018). *Cenchrus americanus* is also considered a nutri-cereal which contains vitamins, minerals, essential fatty acids, phyto-chemicals and antioxidants that can help to eliminate the prevalence of nutritional deficiency diseases (Krishnan and Meera, 2018). It is gluten-free, making it suitable for gluten-intolerant consumers. It is high in dietary fibre, with a low glycaemic index, and can therefore be used as a food for weight control and to reduce the risk of chronic diseases such as diabetes. It is less susceptible to contamination by aflatoxins than many other grains (Dias-Martins *et al.,* 2018), requires less inputs than other grains and is more drought tolerant. These properties make it a highly attractive candidate for large-scale commercialisation.

Pearl millet can be used interchangeably with any other grain in a wide range of foods from breakfast cereals, pasta, breads, biscuits and any other flour-based products. It makes tasty and relatively healthy extruded snacks. It is an excellent food for weaning and as supplementary feeding, especially in the form of pre-cooked porridge (Dias-Martins *et al.,* 2018). The bran that is a by-product of the milling process can be used to make edible oil and deoiled bran can be a source of dietary fibre (Chandiposha *et al.,* 2013). It also has considerable potential in the beverage industry, with millet-based craft beers regularly winning international awards for gluten-free craft ale based on flavour and head retention. A novel beverage application is as a non-dairy probiotic, a fast-growing sector catering to vegans and lactose-intolerant consumers.

Other potential commercial applications include as a stock feed (both the grain and stalks of pearl millet are useful in the production of animal feed, with the grain being especially valued as a protein source for poultry feed), a biofuel (Packiam *et al.,* 2018) and as a source of starch, which has multiple industrial applications (e.g. as tablet disintegrants) (Okpanachi *et al.,* 2018).

Market Potential

The local market alone in Zimbabwe has the potential to absorb several hundred thousand tonnes of pearl millet a year. Currently the actual volumes produced and sold are small, but this is changing as consumer tastes adapt to the needs for a healthier, more wholesome diet. School and supplementary feeding programmes are also a strong driver of potential growth. To encourage more farmers to switch to small grains, in February 2020 the Zimbabwean government increased the price at which it buys pearl millet, sorghum and finger millet from farmers (Mambondiyani, 2020). Market based interventions that encourage smallholders to participate in the market may also improve the uptake of small grains. This could be achieved through setting up platforms that may help in linking farmers to inputs and output markets (UNDP, 2018). It is also important for farmers to aggregate their produce and ensure regular supply in bulk quantity in order to compete with alternative grains like maize.

There is also considerable export market opportunity around pearl millet, driven primarily by the rise in demand for gluten free foods. The global pearl millet market is expected to reach US$12 billion by 2025 (Global Market Insights 2020). Africa dominates global consumption of millets, approximately 40% of global millet consumption is held by African countries which include Niger, Mali, Nigeria, Burkina, and Sudan (Research and Markets, 2019).

Another longer term opportunity lies in malted pearl millet as the basis for brewing. Barley is the major crop used at present, but its key shortcoming is that it is relatively high in gluten, meaning it cannot be consumed by the growing numbers of people around the world who are gluten intolerant. Pearl millet presents an excellent gluten-free alternative to this. This would require investments in both malting and marketing, but with a global market for barley of around 150 million MT/yr, only a small proportion of this would need to switch to pearl millet to create a very substantial growth in demand.

Cultivation/ Domestication Potential

Pearl millet is an exceptionally resilient crop which can be cultivated in areas with drought, low soil fertility, high salinity, low pH or high temperature. It is a warm season crop which will produce tillers at temperatures of 21–24°C and develop spikelets at the slightly higher temperature of 25°C. Pearl millet is tolerant of a variety of soils, including acidic and sandy soils and those which are nutrient poor but it will not tolerate water logging. The plants will grow optimally in a well-drained, fertile soil with a pH ranging between 6.0 and 7.0.

Pearl millet is propagated directly from seed. Pearl millet seed is usually sown directly on fields on hills or ridges with short lived cultivars being planted as soon as possible after the wet season begins in semi-tropical regions. A well-prepared seedbed is important to ensure rapid development of seedlings. Pearl millet seeds are best sown when the soil has warmed to at least 20°C. Seed can be sown in furrows if the soil is light or if the plant is being grown in drier areas, or by broadcasting. Plant population should be 100 000 plants per hectare on average. An inter-row spacing of 45–60 cm is usually allowed between rows.

Pearl millet is a fast-growing crop that will quickly be able to outcompete weeds. It is, however, important to maintain a weed-free seedbed as young seedlings are susceptible to competition. Traditional cultivation of pearl millet in Africa relies on rainfall to irrigate the plants and involves the application of little to no nitrogen fertilizers. The reason for this is often the application of nitrogen promoted vigorous early growth that can result in the plants using up water required at later stages of growth. In more temperate regions where pearl millet is grown as a forage crop, fertilizer application should be based on the results of a soil test. Pearl millet reaches maturity between 50 and 180 days after planting, depending on the variety. The crop is harvested by hand either by cutting the spikes from the plant or by cutting the whole plant.

4.5 Citrullus lanatus

Latin: *Citrullus lanatus*
Family: Cucurbitaceae
English: Kalahari Melon, Tsamma melon, Wild watermelon
Shona: Mashamba
Ndebele: Amajodo
Regions found in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

The Kalahari Melon is the wild ancestor of the watermelon, native to the Kalahari sands of western Zimbabwe. It is an annual herb with prostrate or climbing stems up to 10 m long, covered in long spreading hairs.. Tendrils are robust and usually divided in the upper part. Leaves are more or less narrowly ovate in outline, up to 20 × 19 cm, usually deeply palmately 3-5 lobed; hairy when young, particularly on the veins beneath, becoming roughly punctuate when older, with margins almost entire. Flowers are solitary, axillary, yellow in colour and unisexual on the same plant, with a five-lobed calyx.

In southern Africa the flowering time of *C. lanatus* is mostly from January to April and the fruiting time mostly from February to May (Welman, 2011). Fruits vary considerably in morphology, the wild Kalahari forms are small and round and the cultivated forms are large oblong fruits. In addition, they vary from pale yellow or light green (wild form) to dark green (cultivars), and with or without stripes; the pulp varies from yellow or green (wild forms) to dark red cultivars (Vermaak *et al.,*2011). Fruits are smooth, in wild plants they can be 1.5-20 cm long, greenish with darker mottling, white striped; cultivated fruits are much larger and often more elongated, up to 60 × 30 cm. The flesh in the wild form and some cultivated forms is firm and rather hard, white, green-white or yellowish. In cultivated forms the flesh is somewhat spongy in texture but very juicy and soft, pink to bright red-pink.

The Kalahari melon is highly adapted to surviving drought and the harsh light of the desert environment. Although found all over Southern Africa, it is most closely associated with the Kalahari sands of Namibia, Botswana, south-western Zambia and western Zimbabwe (AfriNatural, 2020). It grows in grassland and bushland, mostly in sandy soils, often along water courses or near water.

Traditional Uses

There is archaeological evidence of the Kalahari melon being in use for over 4,000 years by the San (Vivaness, 2020). Traditionally in Zimbabwe, Kalahari melons have been consumed as food as well as animal feed. The fruit can be eaten fresh or cooked. A prominent traditional dish in Matebeleland is called *umxhanxa* (a mixture of cooked melon, boiled maize grain and sugar) (Moyo, 2020). The tender young leaves and fruits are cooked as green vegetables, while the fruit flesh may be cooked as porridge with maize meal. The hollowed fruit can be used as a container for cooking or storing berries (Alka *et al.,* 2018). The pulp and seeds are prepared in a number of different ways for eating. The fruit excluding the rind, is cut into slices for drying in the sun, or for mixing with meat. Seeds can be roasted and salted and eaten as a snack. Kalahari melon seeds can also produce butter which can be used in place of peanut butter. The fruits and/or seeds are used in different ways in different countries. In the Kalahari region in Africa, *C. lanatus* is used as a source of drinking water. The rind of some cultivars is made into a pickle or a sweet preserve in the United States and in the south of France, the preserved melon is popular for jams. The seeds are usually roasted and salted and the pulp used as soup thickener in Sudan, Egypt and Western Africa (Vermaak *et al.,* 2011).

Rural women of Namibia produce an oil from the seed in their homesteads, and use it for healing applications, massages, cooking oil, and as a skin moisturizer (Lendelvo *et al.,* 2012). The San use the Kalahari melon seed oil to moisturize their skin and encourage hair growth, while the pulp mixed with water is used as a sunblock (Vivaness, 2020). Traditionally, *C. lanatus* melon seed oil is prepared by first pounding the sun-dried seeds to a fine powder and then soaking them in water. This mixture is then filtered through a mesh of straw into a three-legged iron-cast pot. The mixture is then boiled for several hours until the oil separates out from the boiling mixture. The layer of oil that forms on top of the mixture is decanted over time as the boiling process continues. The oil is then stored in glass bottles (Cheikhyoussef *et al.,* 2017). The residue from oil extraction is made into balls that are fried to produce a local snack in Nigeria (Van der Vossen *et al.,* 2004). The seed oil, known since the time of ancient Egyptians, was used to care for the skin to maintain its healthy appearance and aid in its regeneration (Athar and Nasir, 2005).

In addition, the oil has traditionally been used for making soap. Tar extracted from the seeds is used for the treatment of scabies and for skin tanning. In Central America and India the oil extracted from the seeds is applied to herpes lesions, venereal sores, stubborn leg ulcers and the face to treat acne vulgaris (Van der Vossen *et al.,* 2004). It has also been used medicinally as a diuretic, for treating urinary diseases and fever. A patent has been filed which mentions the use of the oil in a self tanning formulation but it is listed amongst several other possible ingredients (Vermaak *et al.,* 2011). The oil cake which remains after the oil has been extracted is used mainly as an animal feed (Bie'nabe *et al.,* 2010).

Commercial History

The main commercially relevant product of the wild Kalahari Melon has been the seed oil. First developed in the late 1990s by Namibian producers, Kalahari Melon Seed oil was adopted by the trade association PhytoTrade Africa in 2001 as a focal value chain for commercial development. This encouraged producers from Botswana and Zimbabwe into the value chain, and today there are a number of businesses across the southern African region engaged in processing and marketing of Kalahari Melon seed oil for both local and export markets. A variety of European cosmetics manufacturers have incorporated the *C. lanatus* melon seed oil into products sold as moisturizers, skin regeneration, and restructuring formulations (Nyam *et al.,* 2009), and this has created a significant draw. As a by-product of the cold pressing process, a seedcake is also marketed in Zimbabwe as a stock-feed.

Potential Commercial Uses

Kalahari Melon Seed oil is already well-established in the cosmetics industry. *C. lanatus* seeds are comprised of 50% oil and 35% protein). The unusual fatty acid content of the oil, over 50% linoleic acid, with significant quantities of oleic, palmitic and stearic acids (Cheikhyoussef *et al.,* 2017), give it an exceptionally light feel, which is highly desirable in cosmetic formulations. Kalahari Melon Seed oil is also useful for soap manufacturing due to its thick, sticky consistency which does not form a hard dry film. The high natural levels of Vitamin E in the oil give it a good shelf-life, and phytosterols within the oil contain strong anti-oxidant properties.

An alternative and very viable use of the oil is as an edible oil. Traditionally consumed as a food oil in Nigeria for many years, under the local name *egusi,* the oil is tasty and healthy. Because it has long been used already internationally, it is also unlikely to require regulatory approval for international market access.

A further potential commercial use, again building on traditional uses, would be to market the seeds as edible seeds. Containing appreciable levels of vitamin C, B2 and key minerals, they are highly prized in some West African countries as a protein-rich snack food (baked or roasted). The growing demand for plant-derived protein continues to drive growth in interest as an alternative to meat in many vegan recipes (Zion Market Research, 2018).

One final potential commercial use would be as a source of a L-Citrulline. This is an amino acid with particular health benefits and medicinal uses (including the commercially interesting treatment of high blood pressure and erectile dysfunction). L-Citrulline is found in all varieties of *C. lanatus,* but there is evidence that it occurs naturally in larger quantities in the wild Kalahari Melon. This is found in the skin of the fruit.

Market Potential

The demand for cold-pressed oils continues to grow, and already exceeds US$30 billion/yr (Allied Market Research, 2019). This is driven by a strong consumer preference for natural alternatives to mineral oils, primarily around health concerns relating to petrochemicals. Kalahari Melon seed oil fits well within this category and there is significant growth potential for its use in the cosmetics industry. Although well-suited to all markets, there is a particular demand for non-greasy oils in the Asian market.

The markets for both the seeds and the edible seed oil are huge. The nuts and seeds market, on the back of the growing vegan population across the world, is currently valued at around USD 1,000 billion/yr, and is expected to reach USD 1,345 billion by 2024 (Zion Market Research, 2018). The edible oil market is some USD 100 billion/yr and is projected to reach USD 120 billion by 2025 (Research and Markets 2020). Undoubtedly the primary focus should be within Africa, where the oil and seeds could be positioned as a premium products targeting health-conscious consumers at a moderate price-point.

The market for L-Citrulline would be harder to identify. However, approaches to specialist manufacturers of amino acids (including the Japanese company whose patented L-Citrulline product uses Kalahari Melon as its base) could yield fruitful results. If this was extracted at source as a by-product of the oil/seed production, it could prove an extremely valuable additional revenue stream.

Cultivation/ Domestication Potential

Kalahari Melons have been cultivated in Southern African with other crops like sorghum and maize since pre-colonial times (Alka *et al.,* 2018). They can grow in any type of soil, but do best on well drained sandy-loam with good moisture retention capacity and high organic matter. Raised beds of 30cm are recommended to improve drainage and rooting. They are propagated by seed. The inter-row spacing (between rows) ranges from 2 to 2,5 m and intra-row spacing (between the plants) 0,5 to 2 m. The seeding rate per hectare ranges from 1 to 3 kgs. It can also be intercropped with maize and sorghum, although this is not recommended under organic production as it poses a higher risk of contamination.

The soil may be fertilised with organic or inorganic material. The crop responds well to fertiliser and the quantity required, depends on the nutrient status of the soil. When using poultry or pig manure, a 10 kg bucket is recommended to cover an area which is 20 cm wide and 15 m long. The same procedure is applicable for the use of kraal manure, but a 10 kg bucket is recommended to cover 5 m. Weed control can be done mechanically using hoes. The most important pests, among others, are aphids, spider mites, spotted and striped cucumber beetle and thrips. A mixture of wood ash with hydrate lime or hot pepper and garlic in water can be sprayed onto the leaves to control some of the pests.

The plant is susceptible to a wide range of diseases, among others, downy mildew, *Cercospora* leaf spot, damping off and anthracnose. Diseases can be controlled by planting disease-free seeds. Other methods such as soil fumigation, good sanitation, crop rotation and mulching are recommended to control diseases. As soon as rotting is noticed, turning the melons so that the rotting side faces upwards can be useful. The fruit of wild melon reaches maturity within 120 to 125 days after planting depending on the variety. When the fruit is ready for harvest, normally the tendril right behind each fruit will dry down to the base. The fresh fruit yield ranges from 20t to 30t per hectare and the seed yield ranges from 0.4t to 0.6t per hectare depending on the management practices, climatic and soil conditions.

4.6 *Cleome gynandra*

Latin: *Cleome gynandra*
Family: Capparaceae
English: Spider-wisp, African cabbage
Shona: Nyevhe
Ndebele: Ulude
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

Cleome gynandra (or nyevhe, as it is commonly known in Zimbabwe) is an erect annual herb which grows up to 0.5 – 1 m in height, many branched and sometimes becoming woody as it ages. It has a long tap root with few secondary roots. The stem is sticky with glandular hairs and marked with longitudinal parallel lines varying in colour from green to purple. The leaves are palmately compound (divided like fingers of a hand), with 3 - 5 leaflets. The leaf stalk is 20 - 50 mm long, also with glandular hairs. The leaflets radiate from the tip of the leaf stalk and taper towards the base. On the under surface they are smooth to finely glandular. The leaves are highly aromatic.

The inflorescences are showy, up to 30 cm long in terminal racemes. The flowers have white petals, fading to a pale pink colour, with long-stalked purple stamens. The fruit are linear capsules, suberect to spreading with a persistent style 2 mm long. The fruit wall is thin-textured and glandular with hairs. The seeds are brown, circular in outline, 1.5 mm in diameter, with an obscurely netted surface. Each plant can have more than 20 seed capsules and each capsule contains more than 50 seeds.

Cleome gynandra is a common plant occurring throughout the tropics and subtropics of Africa. In Southern Africa, it is found in agricultural land and near human settlements (Makgakga, 2004). Although rarely cultivated, people often leave it when it occurs naturally as a weed, and it is commonly found in maize fields throughout Zimbabwe.

Traditional Uses

Nyevhe is regarded as an important leafy vegetable in many parts of Africa. Young fresh leaves are harvested for preparation as a side dish. They are cooked in water with a little salt and some tomatoes, and are eaten as spinach with thick porridge (sadza). They can also be mixed with other vegetables such as *Bidens Pilosa* (black jack) and species in the Solanum nigrum complex or Amaranthus species. They are also harvested, dried in shade and stored for use during the winter months (Makgakga, 2004). One major issue with nyevhe is the bitterness that naturally occurs in the leaves. Various methods are used to ameliorate this. In Kenya leaves are steeped overnight in milk. In Botswana and Zimbabwe, initial blanching of leaves is performed, the water discarded and cooking continued in fresh water (Sogbohossou *et al.,* 2018). In Thailand the leaves, young shoots and flowers are fermented in salt water prior to serving as a side dish. Seeds are used for mustard and contain edible polyunsaturated oil (Mnzava and Chigumira, 2004).

In addition to consumption as food, the leaves, stems and roots of *C. gynandra* are widely used in traditional medicine. Boiled leaves are commonly used to boost immunity in women and children, to treat blood loss in new mothers and after injury, and as a general medicinal meal. It is believed that regular consumption of the leaves by pregnant women will ease childbirth by reducing the length of their labour, and will help them regain normal health more quickly after giving birth. In some communities, consumption of the vegetable by pregnant women is almost mandatory (Mishra *et al.,* 2011). Leaf infusions are used to treat diarrhoea and anaemia, while root infusions are used to treat chest pains. *C. gynandra* has also been used to treat various digestive disorders, inflammation, epilepsy and malaria (Mnzava and Chigumira, 2004; Sogbohossou *et al.,* 2018). Sap from leaves may be used as an analgesic, particularly for headaches. Sap from pounded young leaves is also squeezed into ears, nostrils and eyes to treat epileptic fits and earache (Mishra *et al.,* 2011). Seeds are sometimes fed to birds.

Commercial History

Nyevhe is a popular indigenous vegetable and has always been produced and sold on informal markets in Zimbabwe. Indeed, the harvest and sale of traditional vegetables is an important source of economic livelihood to many rural families. The collection of wild and traditional vegetables for sale is traditionally the domain of women. In the case of *C. gynandra,* it is a common practice, especially amongst elderly women, to sell the vegetable to urban consumers at business centres, street corners and market places (Maroyi, 2011). This practice also provides substantial opportunities in many rural and peri-urban areas. For fresh indigenous vegetables, trade commences soon after the first rains around mid-November to April/May period when winter begins. *C. gynandra* is the first indigenous vegetable to be available as they are triggered by the first rains and grow as weeds (Gwenero *et al.,* 2003). Limited cross-border trade of the dried produce also takes place, especially for example from Zimbabwe to Botswana, although no statistical data is available (Mnzava and Chigumira Ngwerume, 2004). In the 2020 ZIMVAC assessment, 80% of rural survey respondents reported regular consumption of nyevhe.

Recently there has been an upsurge in interest in *C. gynandra* on more formal Zimbabwean markets, and dried *nyevhe* can regularly be found for sale supermarkets. This is a reflection of the growing consumer interest in traditional foods, mostly driven by health concerns. However, *C. gynandra* has yet to make it into any form of commercial production, as a result of which there are still significant hurdles to its commercial development, including a lack of seed, low productivity, high perishability and poor quality of processed products (mostly dried leaves) (Gwenero *et al.,* 2003; Orchard and Chigumira Ngwerume, 2003). In East and southern Africa, limited quantities have been produced under irrigation and seed of improved cultivars is commercially available which could increase production (Mnzava and Chigumira Ngwerume, 2004).

Potential Commercial Uses

Like most indigenous leafy vegetables, *C. gynandra* is a source of micro-nutrient vitamins and minerals (Uusiku *et al.,* 2010). A comparison of the mineral, chemical and antioxidant qualities of *Cleome gynandra* with two widely consumed commercial vegetables, *Brassica oleracea* (cabbage) and *Beta vulgaris* (beetroot), shows that nyevhe has higher concentrations than either of them of phosphorus, potassium, calcium, iron, zinc, ascorbic acid, total phenolics and flavonoids (Moyo *et al.,* 2017). Given the prevalence of micro-nutrient deficiencies in Zimbabwe (in the 2020 ZIMVAC assessment, only 31% of rural survey respondents were assessed as having an acceptable diet), there is a clear need for Zimbabwean consumers to increase their intake of micro-nutrients, and nyevhe is a popular and effective tool towards achieving this. The single most important potential commercial use of nyevhe in Zimbabwe is therefore simply as a fresh or dried leafy vegetable

C. gynandra also has considerable potential as a herbal remedy. Pharmacological analyses of the leaves have shown high concentrations of flavonoids, tannins, glucosinolates, iridoids and essential oils. These contribute to antibacterial, antifungal, antiviral, analgesic, anticarcinogenic and anti-inflammatory properties (Adhikari *et al.,* 2018). As the plant is already consumed as food, without any adverse toxicological effects, it is known to be safe and is there a strong candidate for the development of novel herbal medicines in a variety of formats (Singh *et al.,* 2018)

A third potential commercial use of *C. gynandra* is as a tick repellent in veterinary medicine. The leaves contain an essential oil (responsible for their intense aroma and comparable to mustard oil) which has been shown to exhibit repellent and acaricidal properties to larvae, nymphs and adults of the ticks Rhipicephalus appendiculatus and Amblyomma variegatum (Mnzava and Chigumira Ngwerume, 2004). In comparison with currently used chemicals

to control tick infestations in livestock, *C. gynandra* shows 90–100% efficacy (Adenubi *et al.,* 2016).

Market Potential

The fact that Zimbabwe imports vegetables from neighbouring South Africa suggests that there is potential unfulfilled demand locally for *nyevhe*. Historically indigenous vegetables have been ignored by policy-makers, but that is changing now, along with consumer interests. The rise in metabolic disorders in Zimbabwe, leading to increased risk of high blood pressure, diabetes, stroke and heart disease, has driven consumers to begin rethinking their diet. At present the demand is not being met, and there is a strong need to remedy this, which will also require concerted efforts to overcome some of the challenges inherent in marketing indigenous vegetables to Zimbabwean consumers.

Foremost amongst these challenges is a consumer stigma towards indigenous vegetables, with a widely-held perception that they are "old-fashioned", "rural" and that their consumption is a sign of poverty. One consumer perception study showed a clear correlation between the age of Zimbabwean consumers and the likelihood of them buying indigenous vegetables, with likelihood increasing significantly with age (Dube *et al.,* 2016). Overhauling and revamping the image of *nyevhe* is clearly required, presenting it in a modern and contemporary manner to a younger consumer demographic.

There is also an opportunity to export dried C. gynandra to neighbouring countries or overseas to Zimbabweans in the diaspora. Traditional vegetables are becoming an increasingly attractive food group for the wealthier segments of the populace in East Africa and South East Asia (Akinola et al., 2020). Such vegetables are slowly moving out of the underutilized informal market category into the commercial mainstream. The global dehydrated vegetable market is expected to witness a rise in the upcoming years due to a demand for healthy convenient food with a longer shelf life. Advancements in food technology are expected to support that market (Fortune Business Insights, 2019). Proper packaging, information on the nutritional value of C. gynandra, the knowledge on how to prepare may improve the acceptability and preference for consumption on the global market (Akinola et al., 2020)

Cultivation/ Domestication Potential

Cleome gynandra is currently semi-cultivated, it is usually left out deliberately when weeding in fields and it can be picked from homestead and fallow fields (Nyaruwata, 2019). It grows from seed which are dispersed and germinate during the rainy season. Although it is considered an agricultural weed, it can be easily grown as a valuable agricultural crop (Makgakga, 2004). The species grows well during the warm season when supplied with adequate water. It can tolerate some degree of water stress but prolonged water stress affects flowering. *C. gynandra* can grow in areas with short periods of useful rainfall. The species cannot withstand flooding. It is sensitive to cold and does not grow well when temperatures drop below 15°C (van Rensburg *et al.,* 2012). In terms of the growth media, it prefers sandy loam soils, rich in organic matter.

Seeds can be sown in seedbeds or directly in rows in the field. Transplanting or thinning is necessary as germination is usually uneven. Recommended spacing is 25-50 cm between rows and 15 cm between plants. When using chemical fertiliser, 2:3:4 mixtures are the best and can be applied in relation to soil tests results. For good growth, ammonium nitrate must be applied at the rate of 20 gram per metre when the plants have about 5 to 6 leaves. One teacup of ammonium nitrate should be spread along a row of 10 m. When using manure either poultry or pig manure, one 10 kg bucket can be applied in a band of about 20 cm wide over a length of 15 m, mixed into the top soil, water the band thoroughly and wait one to two weeks before transplanting. When using cattle manure, the same procedure applies however one 10 kg bucket is only sufficient over a length of 5 m. In a recent study, goat manure performed better than cattle and chicken manure with the highest germination, plant height and leaf yield (Mwarozva *et al.,* 2019). Thus production of *C. gynandra* using goat manure is recommended for optimum yield.

A number of pests infest *C. gynandra.* The most important ones are beetles and hurricane bugs, aphids, nematodes etc. Controlling pests and diseases requires regular monitoring of the crop. It is important to detect pests before they cause damage to the crop. Crop hygiene is very important, in particular removal of old crops and destruction of weeds. Handpicking and destruction of the noticeable pests helps to reduce damage particularly in the early stages of the crop. Growing strong smelling plants such as garlic, onion or parsley near the

crop are reported to reduce infestations. Encourage natural enemies such as wasps.

A mixture of chilli, soap, garlic and paraffin has shown to be an effective control method in trials in Namibia or spraying plants with a soapy solution (bar soap) has been found effective against Bagrada bugs. It helps to wash off young bugs. (van Rensburg *et al.,* 2012

In terms of readiness to harvest leaves, *C. gynandra* has a short growth period and are ready for first harvest about 30 days after transplanting, usually within 3-5 weeks after sowing. Individual leaves and growth tips can be harvested or the whole plant can be cut back. Cutting back the shoots 10-40 cm from the ground help in the development of new side shoots. The harvest can be repeated 2 to 4 times and even more during the season, depending on the soil fertility and moisture conditions.

Seed can be harvested when pods are fully ripe and yellow but before they open naturally to prevent shattering. Seeds can be threshed by hand and cleaned by winnowing. Dried seed must be kept in a cool dry place. Seeds should be kept for at least 3 months before planting.

4.7 Cucumis metuliferus

Latin: *Cucumis metuliferus*
Family: Cucurbitaceae
English: Horned cucumber, Jelly melon, Kiwano
Shona: Magaka
Ndebele: Umhlagahlaga
Regions in Zimbabwe: Zambezi, Kalahari, Central Save-Limpopo

Botanical Description

Cucumis metuliferus, the horned cucumber, is one of the many important food plants of its genus. It is an annual climbing or occasionally trailing herb. The vegetative parts are rough with spreading hairs. Stems grow up to 3 m long, radiating from a woody rootstock and are covered in bristly hairs. The leaves are broadly ovate in outline, up to 90 x 100 mm, usually palmately 3-5-lobed, with the veins below very roughly hairy and the margins minutely toothed. The petioles are up to 100 mm long. Male and female flowers appear on the same plant (monoecious). They are usually solitary or in small clusters, yellow or pale orange, up to 2.5 cm in diameter (Hyde et al., 2002). The fruit is ellipsoid-cylindrical, 60-150 mm long, 30-60 mm across when ripe, and is covered in stout spines. The fruits are grey-green to orange yellow, often mottled, turning bright orange-red when ripe and edible. Seeds are flattened, 6-9 mm long, numerous, embedded in a light green or emerald-green, jelly-like flesh.

Cucumis metuliferus grows naturally in tropical Africa. In Zimbabwe, it is cultivated across all ecological regions. This species generally grows in shallow or deep, well-drained sand, mostly in alluvial soil on river banks, in river beds or flood plains; it is also recorded from clay or loam soil and rocky slopes. The horned cucumber also grows in disturbed areas and abandoned land. (Welman, 2009)

Traditional Uses

It is mainly the fruits of *C. metuliferus* that are eaten, although in some parts of Africa the leaves are also used as a vegetable. The fruit has an intense, tangy flavour, often described as being a combination of lime, cucumber and banana. In Zimbabwe fruits are eaten raw and young leaves are stripped from the stems, washed and boiled just like musk pumpkin leaves (*Cucurbita moschata*), with peanut butter added prior to serving (Wilkins-Ellert, 2004). Fruits from wild-growing plants are often bitter and considered inedible/poisonous. The Khoisan roast the fruit and then strain the flesh (Usman et al., 2015). The leaves are also cooked like spinach or mixed with maize meal (Welman, 2009). The fruits are peeled and eaten in either the immature or the mature stages. Mature fruits may also be split open and dried in the sun for later use. In Botswana the San prepare the fruits by roasting them on the coals of the fire (Wilkins-Ellert, 2004). In the wild, the horned cucumber tends to yield more bitter fruits which contain significant levels of the toxic triterpene. This is absent from the sweeter cultivated varieties.

The species has also been used as traditional medicine to cure a number of ailments. The leaves widely reported as a cure for malaria. The seeds are used to treat worms and parasites, being dried, ground into a fine flour and then made into an emulsion with water and eaten. The boiled root is used for the relief of pain after childbirth, and is also known as an effective treatment for gonorrhoea (Welman, 2009). There are strong magico-spiritual properties associated with the plant. In the Okavango region of Botswana, for example, the roots are pounded, mixed with fat and smeared on the body to prevent evil spirits from entering the house. The decorticated fruit, macerated in distilled palm wine or lemon juice. is used to treat smallpox and skin rashes (Wilkins-Ellert, 2004).

Commercial History

The horned cucumber is well-known to Zimbabwean consumers and has been traded on informal fruit and vegetable markets for years. It is occasionally found on supermarket shelves as well. It has a similar story in many other African countries, and is a popular fruit with Africans in the diaspora. It has also gained some prominence internationally. Export production started in New Zealand in the 1980s, having allegedly been introduced there by Zimbabwean farmers in the diaspora. Early marketing attempts ran into problems with the name (neither "horned cucumber" nor "jelly melon" apparently having sufficient appeal to help market this odd-looking fruit). It was then rebranded as the "Kiwano" fruit, in an attempt to make it more appealing to consumers in the target markets of the US and Japan. This was moderately successful, and it is now grown commercially in California for the United States market, and in Israel and Kenya from where the fruits are exported to markets in Europe (Wilkins-Ellert, 2004).

It has become naturalized in Australia, and is reported as adventives in Croatia (Lim, 2012). In some Western countries, C. metuliferus is currently mostly marketed as an ornamental for its decorative fruit, with a unique appearance and extended keeping qualities (Wilkins-Ellert, 2004).

Potential Commercial Uses

The horned cucumber meets many of the requirements of a novelty health food. It has a respectable balance of vitamins and minerals (vitamin A and C, potassium and zinc), is low in sodium, lipids and carbohydrates (Rani et al., 2019) and is cholesterol free. The seeds contain a rich oil with a high content of unsaturated fatty acids, which help in controlling of blood pressure and preventing cardiovascular diseases (Ferrara, 2018). It also has considerable visual appeal, being an unusual and striking fruit, and has a remarkable shelf-life of at least 6 months or more from harvest.

There is also potential for value addition in the food industry. Some observers noted that the fruit can be eaten like an ordinary cucumber, while Parsley (1981) suggests that the refreshing jelly is best scooped out of the shell with a spoon or used in fruit salad. A jelly can be made from the fruit by boiling it until soft, straining it and boiling the fruit pulp again with a cup of sugar for each cup of water. The fruit can also be cut into cubes and pickled in vinegar or added to cocktails (Welman, 2009). Sun-dried slices of the fruit make an interesting vegan alternative to biltong. The fruit pulp also makes an excellent beverage ingredient in mixed fruit smoothies.

C. metuliferus possesses several phytochemicals of pharmaceutical interest, and has considerable and diverse potential uses as a herbal remedy. Researchers have shown strong antimalarial activity, analgesic effects, antiviral activity, antimicrobial activity, anti-ulcer activity, anti-diabetic activity and anti-protozoan activity. Doses of fruit pulp extract have also been shown to improve sperm count and motility (perhaps associated with the very high levels of zinc), suggesting potential use to help boost male fertility.

Another interesting potential industrial application is derived from the exceptional shelf-life of the fruit, most likely associated with free radical scavenging anti-oxidants in the peel. Researchers have shown that adding a fruit extract into a cellulose acetate can create an active coating for food packaging that significantly extends shelf-life (Arrieta et al., 2020), suggesting a possible application of the extract at an industrial scale for fatty food and fresh fruit packaging.

Market Potential

There is already a niche market in Europe and North America for C. metuliferus as a novelty/ornamental fruit. The market size is hard to assess, but the overall market for organically-certified fruit and vegetables was USD 30.7 billion/yr in 2019 and is expected to reach USD 55.8 billion/yr by 2027. Other market opportunities include the Ready To Drink fruit beverage market (USD 34 billion/yr), the craft spirits market (currently growing at an astonishing 33.4% annually around the world, and heading for USD 80 billion/yr by 2025) and the vegan market (USD 13 billion/yr).

Locally, there is also significant growth potential in demand for horned cucumber products as a fresh fruit. Zimbabwean consumers are becoming steadily more interested in the health benefits of indigenous fruits and vegetables, as evidenced through the appearance of these products in speciality restaurants and on supermarket shelves around the country. There are also several initiatives being promoted by the Government and other stakeholders to increase awareness and uptake of these products by Zimbabwean consumers, including cooking demonstrations and competitions. The 2020 Zimbabwe Vulnerability Assessment found that 80% of rural households in Zimbabwe were consuming at least one indigenous vegetable type on a regular basis.

As the world fights a global pandemic, and set against the backdrop of growing antibiotic resistance, the global herbal medicine market has undergone a dramatic resurgence. Currently estimated at USD 148 billion/yr in 2020, it is projected to reach USD 219 billion by 2026 (Market Watch, 2021). In China, 40% of all pharmaceutical sales are from herbal medicines, and the herbal medicine industry is estimated at US$36 billion/yr. There is also a well-documented male infertility crisis around the world, with an overall decline of over 50% in male sperm counts. This is particularly pronounced in some Western countries, and is primarily attributed to diet. This would appear to create a substantial opportunity for herbal products from C. metuliferus marketed specifically to improve male fertility.

Finally, the global fresh food packaging market is estimated at USD 80 billion/yr in 2020 (Markets and Markets 2021), growing to USD 95 billion/yr by 2025. This is on the back of rising demand for meat, vegetables and fruit.

Cultivation/ Domestication Potential

The horned cucumber has been cultivated for years in Zimbabwe by small scale farmers, usually intercropped with maize. It is a warm-season crop which grows in tropical to subtropical and warm temperate regions. It tolerates a wide range of soil types but grows best in rich and well-drained moisture-retentive soils, usually clay or loamy soil with a pH range of 6.0 to 6.5. Choosing an area near a trellis or fence is essential to promote climbing. A planting density of 10,000 plants per ha have produced good yields in Israel. A planting depth of 1-2 cm is recommended. In-row spacing of 45-60 cm, leaving a space of 1.8 m between rows. The soil should be consistently kept moist down to about 2.5cm for the seed to germinate. Germination usually occurs within two or three weeks.

Under irrigation the plant should be provided with 25 mm of water per week, although the soil should be allowed to dry between irrigation sessions. Fertilizer with a 4-8-5 or 6-10-10 N-P-K ratio can be applied according to the soil analysis results (Ketchum, 2020). Organic mulch can be applied, such as straw or wood chips, around the base of the plant to help the plant retain moisture and prevents weed growth. Picking the weeds by hand as they appear is known to be useful in preventing diseases such as the cucumber mosaic virus and tobacco ringspot virus. Under large scale production it might be necessary to employ other efficient methods of controlling weeds such as mechanical methods or herbicides application. Like all cucurbits they seem to be prone to mildew and whitefly. From recent trials, it appears that *C. metuliferus* is resistant to the root-knot nematode and some mosaic viruses (Exposito *et al.,* 2017). Integrated Pest Management can be employed to address the respective diseases.

Flowering starts about 8 weeks after sowing the seed, with male flowers appearing first, followed after several days by female flowers. Under field conditions, it takes approximately 15 weeks for the species to reach maturity from sowing (Wilkins Ellert, 2004). Stems of horned cucumber die back at the end of the growing season while the fruits remain attached and continue ripening to a bright orange colour. They may be harvested over successive months. Care is needed during picking because the stiff sharp hairs on the stems and the spiny 'horns' on the fruits can easily pierce the skin; it is recommended that gloves be worn during harvesting. New Zealand growers have recorded a harvest of 20 tonnes of fruit per hectare, in California about 8 tonnes/ha whilst growers in Israel have harvested up to 46 tonnes/ha(Welman, 2009). There are some known and named varieties of the horned cucumber making it easy to select cultivars for commercial production. Another commercial advantage is that the fruit remains in good condition for about 6 months without cold storage (Arrieta *et al.,* 2020).

4.8 *Cyperus esculentus*

Latin:	*Cyperus esculentus*
Family:	Cyperaceae
English:	Tiger Nut
Shona:	Pfende
Ndebele:	Inqodi
Regions in Zimbabwe:	Zambezi, Kalahari, Central, Save- Limpopo

Botanical Description

Cyperus esculentus, the Tiger nut or Yellow Nut-sedge, is a grass-like plant belonging to the sedge (*Cyperaceae*) family. It is perennial, erect, robust and fast-growing. The rachis, which ranges from 2 to 9 cm long, is terminated by an umbel, an inflorescence with golden-brown, flower-bearing rays in a cluster springing from the same point at the tip of the peduncle. The umbel consists of several erect, short rays and two to nine strongly ascending longer rays. The umbel is surrounded at the same level with between three and nine leaves.

The distinctive feature of *C. esculentus* is the extensive underground network created by the fibrous roots, rhizomes and tubers. Buds on the tubers sprout and grow to establish new plants and eventually form dense patches of vegetation. Tiger nut tubers grow at the ends of rhizomes, are mostly round, hard, smooth, scaley when immature and some 6 – 10mm long. At the end of the growing season and near maturity stage the colour of tubers changes from white to yellow and the dimension is increased. These tubers are the edible part of the plant, referred to as the "Tiger nuts".

Cyperus esculentus is found worldwide in warm and temperate zones (Saha *et al.,* 2019). In Zimbabwe it occurs in all ecological regions. It is prevalent in lawns, cultivated areas, turf areas, landscape beds, gardens, fields, pastures, roadsides, edges of forests, grasslands, riverbanks, irrigation canal banks, and disturbed areas (Saha *et al.,* 2019). It does not tolerate salinity.

Traditional Uses

Tiger nut has been widely used in Zimbabwe for both animal feed and human consumption (Maroyi 2013, Campbell et al 1987). Although information on traditional uses of *C. esculentus* is scarce in Zimbabwe, a number of uses have been documented for other various countries. In Spain, these tubers are mainly used to make a milklike beverage called *"horchata de chufa."* This beverage is a non-alcoholic refreshing drink of dairy appearance and is usually consumed in summer. This beverage was originally made by Muslims and now is widespread in Spain and several other European and Latin American countries (Sanchez-Zapata *et al.,* 2012).

Elsewhere in Africa, there is considerable literature around its consumption in Nigeria (e.g. Toungos and Babayola, 2019), where the Tiger nuts are called *"aya"* and are usually eaten fresh, or sometimes dried and later rehydrated before consumption. A snack is also made by toasting the nuts and coating them with sugar, popular among the Hausa children of Northern Nigeria. A drink known as *"kunun aya"* is made by processing the nuts with dates and later sieved and served chilled.

Commercial History

International trade in *C. esculentus* dates back to the 8th century, when Arab traders introduced its cultivation to the Mediterranean region of Valencia (Spain) for the production of *horchata de chufa* (Gambo and Da'u, 2014). Over the years, interest in this crop has grown in Spain to such an extent that the Valencian community has developed specific legislation regarding chufa and horchata qualitative parameters (Pascual *et al.,* 2000). The annual value of tiger nut production in Spain is close to EUR 3.3 million (Sanchez-Zapata *et al.,* 2012). The popularity of a beverage derived from tiger nut has of late extended to other countries such as France, UK, Portugal, Argentina and the USA (Sanchez-Zapata *et al.,* 2012). In the UK, the Tiger Nut Company sells a range of Tiger nut products, including flour, raw nuts, granola, nut flakes, chocolate, nut bars and others.

The Tiger nut has also been successfully commercialised in some African countries. Ghana is reported to be exporting close to 100MT/yr of dried Tiger nuts to markets including the UK, Japan and the USA (Donkor *et al.,* 2019), with *C. esculentus* farming having become a leading enterprise in the Kwahu East District in the Eastern region of Ghana (Obeng-Koranteng, 2017). Other countries with commercial, and in some cases organically-certified, export production of Tiger nuts include Benin, Mali, Nigeria and South Africa.

Potential Commercial Uses

The positive nutritional composition and pleasant flavour of Tiger nuts make *C. esculentus* a potentially important food crop in many parts of Africa and Europe. From a nutritional standpoint, the tubers contain almost twice the quantity of starch as potato or sweet potato tubers (Kuner *et al.,* 2002) (Gambo and Da'u, 2014), are high in calcium, sodium and phosphorus (with lower levels of magnesium, manganese, iron, zinc and copper) (Shaker *et al.,* 2009), and high in vitamins B1 and C (Bizane and Arslanoglu, 2020).

The versatile nature of Tiger nuts mean that they can be used in a wide variety of applications. There are already many different food products using them as a base, but there is still room for more innovation. Roasted dried tubers can be processed into a flour, resembling a nut flour and useable in baking, specifically of gluten free products (Oladele and Aina, 2007) (Gambo and Da'u, 2014). Tiger nuts are popular for their "milk", which is an excellent non-dairy alternative in fermented products such as yoghurt (Toungos and Babayola , 2019), and as an ingredient in alternative ice creams. The milk can also be used as a base for the development of both alcoholic and non-alcoholic beverages (e.g. *Horchata* in Spain, *Kunnu* in Nigeria) (Toungos and Babayola 2019). Raw, roasted and/or flavoured Tiger nuts are a healthy snack, and go particularly well in combination with chocolate.

Tiger nuts also yield an oil (20-36%), with potential use in the food, bio-fuel and cosmetics industries. This oil can be classified in the oleic-linoleic oil group due to its high content of oleic acid (66%) (Pascal et al., 2000). In the food industry it could be used as a potential supplement to, or substitute for, olive oil, given its fatty acid composition and other physicochemical properties. Researchers have suggested that oil yields of as much as 1.5 MT/ha (based on a tuber yield of 5.67 t/ha and an oil content of 26.4%) night be feasible (Toungos and Babayola , 2019). This compares extremely favourably to other oil-bearing crops (e.g. coconut, groundnut, sunflower etc,) for which average yield is around 0.5 MT/ha.

Market Potential

There are potentially four different avenues to market for Tiger nut from Zimbabwe. The first would be as a food for the local and regional Southern African markets. This would take time, as Tiger nut is virtually unknown to local consumers, but the growing demand for healthy, plant-based food and cosmetics products among consumers creates a significant opportunity. The COVID-19 pandemic has also driven a change in local consumer patterns, and Zimbabweans are becoming more health-conscious and more concerned about immune boosting-products (ZimTrade, 2021).

The second is as a food for the export market. Recent market trends and forecasts predict significant market potential for Tiger nut as an export product (Value Market Research, 2020), driven by the unstoppable surge of interest in plant-based diets (and especially plant sources of protein). Europe, North America and Asia are all seen as growth areas for Tiger nut products, whilst in Latin America Tiger nut demand is expected to rise in the form of ground flour in bakeries (Transparency Market Research, 2017).

A third opportunity for *C. esculentus* on the market is centred on its application in the bio-fuel industry. The relatively high yields of oil per hectare make this an attractive biodiesel option, and research has already confirmed both its suitability as a substitute for petroleum diesel in motor vehicles and generators and that it meets international standards for automotive use (Ofoefule *at al.,* 2013). The global bio-fuels market size was valued at USD 135.7 billion in 2019 is expected to grow at a compound annual growth rate (CAGR) of of 6.9% (Grand View Research, 2020).

The fourth, and potentially most interesting, opportunity for Tiger nut lies in its value as a source of edible oil, directly competing with olive oil and similar oleic-rich cold-pressed cooking oils. This market, over USD 100 billion/yr, is experiencing robust growth around the world. Average per capita consumption of edible oil us 27kgs/year in developing countries, creating a potential annual demand in Zimbabwe alone of 400,000 MT/yr.

Cultivation/ Domestication Potential

C. esculentus has a very long history of domestication, with dry tubers having been found in tombs from predynastic times, some 6000 years old (Bazine and Arslanolu, 2020). It has been successfully cultivated in Northern Nigeria and Ghana; the Ivory Coast has exported 2,300 tonnes of tubers to Spain yearly (Pascual *et al.,* 2000). The species is very persistent once established due to its extensive root system. However, it is important to note that the species is also sometimes regarded as an invasive weed. The Tiger nut can be produced annually by seeds or perennially by corm like solid bulbs at the base of a leaf fascicle or by rhizomes (Bazine and Arslanolu, 2020).

Cyperus esculentus cultivation requires a mild climate because low temperatures, shade, and high light intensity can inhibit flowering. Tuber initiation is inhibited by long photoperiods and high levels of nitrogen as well. Planting is normally done on flat soils or ridges. The separation between ridges should be approximately 60 cm and seeds (tubers) are planted manually. In row spacing may vary from 15 to 20 cm and seeding depth is around 8 cm. A seeding rate of about 120 kg of tubers per hectare is recommended. Time of planting depends on geographical location. Tubers can develop in soil depths around 30 cm. They grow best on sandy, moist soils at a pH which ranges from 5.0 – 7.5. The densest populations of *C. esculentus* are often found in low-lying wetlands. They do not tolerate salinity.

Tubers usually develop about 6 – 8 weeks after seedling emergence and the maturity period for the crop ranges between 90 – 110 days. The leaves are scorched at the time of harvest. The average yield can be between 10 and 19 t/ha (Rossello-Soto *et al.,* 2018). Harvesting can be done manually or with a combine harvester, by pulling the tiger nut out of the ground. Immediately after harvesting, the tiger nuts are washed and sun dried, the drying process can take up to three months. The drying process ensures a longer shelf life and it prevents rotting or other bacterial infections. Temperatures and humidity levels have to be monitored very carefully during this period. Tiger nut can be stored dry and rehydrated by soaking to ensure acceptable sensory quality. (Toungos and Babayola, 2019)

4.9 Eleusine coracana

Latin: *Eleusine coracana*
Family: Poaceae
English: Finger millet
Shona: Zviyo
Ndebele: Uphoko
Regions in Zimbabwe: Zambezi, Kalahari, Central and Save Limpopo

Botanical Description

Eleusine coracana (finger millet) is an annual herbaceous plant. It is a tufted, laterally flattened grass that grows to a height of 60-120 cm. It produces tillers in addition to branches sent out at the rounded nodes in succession. The root system is fibrous and remarkably strong, permeating the soil thoroughly. Leaf blades are shiny, strongly keeled and are 220-500 mm long and 6-10 mm wide. The leaves and culms are typically green in colour. The inflorescence is a panicle with 4 to 19 finger-like spikes that resemble a fist when mature, hence the name finger millet (Heuzé and Tran, 2015). The spikes bear up to 70 alternate spikelets, carrying 4 to 7 small seeds varying from 1-2 mm in diameter; caryopsis nearly globose to somewhat flattened, smooth or tugose, reddish-brown to nearly white or black of 210-620 mm tall. The seed pericarp is independent from the kernel and can be easily removed from the seed coat.

It is considered to be of Indian or African origin, however it is widely cultivated in tropical Asia, East and Southern Africa (Duke, 1983). In Zimbabwe it thrives in regions characterised by low, erratic and poorly distributed rainfall (Mukarumbwa, 2010).

Traditional Uses

Finger millet has been a staple food grain for many people, especially in dry areas of India, Nepal, Sri Lanka and Africa, for thousands of years (Kubo, 2016). Although modes of preparation vary widely, throughout Africa the dominant format for finger millet has been as the base for porridge and related beverages. The grain can also be cooked whole, or ground and used as a flour in cakes and puddings. The flour makes a very fair unleavened bread if it is first soaked overnight in water (Fern, 2014). It is often used in making fermented foods. The grain also lends itself well to malting and is a popular base for making local beer and other alcoholic or non-alcoholic beverages. In Zimbabwe, many communities use finger millet as the basis for beer brewed for traditional ceremonies to appease local ancestors (Muchineripi, 2008). It has been highly valued as a reserve food in times of famine mainly due to its ability to sustain drought during production and long shelf life.

Commercial History

Distribution, linguistic and historical evidence suggest an African rather than Indian origin for *Eleusine coracana* (Hilu and de Wet, 1976). Having been used commercially for centuries, the species has benefited from considerable amounts of innovation and selective breeding, with different cultivars being preferred for different applications. White cultivars have been developed mainly for the baking industry, the brown and light brown types used for porridge while the brown cultivar is utilised for brewing traditional opaque beer in Southern Africa (Ramashia *et al.,* 2019). The grain is also cultivated in Taiwan, China, Japan (to a limited extent), as well as in South Carolina in the United States. About 55-60% of globally produced finger millet is cultivated in Africa, mainly in Ethiopia, Kenya, Nigeria, Malawi, Tanzania, Uganda, Zambia and Zimbabwe (Ramashia *et al.,* 2019).

Despite its historical and traditional use, Zimbabwean farmers are reluctant to grow finger millet, citing high labour costs, weeding, bird scaring, harvesting and grain processing compared to maize (UNDP, 2019). Other causes for the general maize preference include lack of technology, unavailability of fertilizers and poor market infrastructure in the small grains industry. Industrial processing of millet meal in Zimbabwe has been relatively limited (Phiri *et al.,* 2019). Finger millet flour has however been

sold in retail shops for quite some time. Most of the trade is still done informally by private or independent traders who buy grain from small scale farmers. Small grains such as sorghum and millet are mainly produced in drought-prone areas of the country and a recent study notes that farmers complain they lose a large part of the crop to birds (Chingarande *et al.,* 2020). As a result, small grains produced in these areas are mainly for household consumption and where there is surplus, the low volumes that reach markets are sold by women mostly through barter trade, in exchange for maize. In few cases, surplus sorghum/millet is channelled to GMB at the same price as maize.

Potential Commercial Uses

The rationale for promoting finger millet is clear, on the basis of its excellent storage properties, nutritive value, resistance to disease and tolerance to soil moisture stress. However, there has to be a compelling commercial argument for its adoption by famers, and this is where investment is needed. Fortunately there are many potential commercial applications for finger millet that remain underexplored at present.

Perhaps the single biggest commercial opportunity for finger millet lies in the fact that it is a substantially healthier alternative staple grain than maize. Its nutritive value is outstanding; it is a good source of fibre, micro-nutrients and vitamins (Luitel *et al.,* 2020). It contains the highest amount of calcium amongst all the food grains (Ihekoronye *et al.,* 1985) (Audu *et al.,* 2018), and is exceptionally high in iron, potassium and the B vitamins. It has an extremely low glycaemic index, and epidemiological reports indicate that regular consumption of finger millet reduces incidences of diabetes mellitus, cardiovascular disease, duodenal ulcer and other gastro-intestinal tract related disorders (Audu *et al.,* 2018). It also supports immune system functioning and is seen as helpful in the prevention and treatment of cancer. It is gluten free, high in dietary fibre and an excellent source of key amino acids.

With the rise in metabolic and lifestyle diseases, Zimbabwean consumers are rapidly becoming more health-conscious. Larger scale promotion of finger millet on local and regional markets as a healthy food will undoubtedly result in increased levels of uptake from consumers in its traditional form. However, there are many novel modes of use that are likely to enhance this, including specifically presenting finger millet as a weaning food, sprouted seeds for use in salads and health foods, popped grain as a snack food and as the basis for various fermented foods.

One key potential growth area lies in the use of finger millet as a base for beverages, both non-alcoholic and alcoholic. In malting, finger millet grain has a higher enzyme activity than all other major cereals except barley, making it very suitable for brewing (Fern, 2014). The growth in demand for craft beer is one such opportunity, and the surge in interest in traditional mahewu-type beverages is another. Fermented finger millet can also be used as the base for a distilled alcoholic beverage, as is often traditionally consumed in India.

Finger millet can also be commercialised as a forage crop, stalks are cut at vegetative stage (around 80 days after planting) for production of good quality hay or silage (Heuze *et al.,* 2019). In addition, on the basis of studies done recently finger millet has potential to produce ethanol, bio-ethanol is currently considered to be one of the most promising substitutes for petroleum (Yemets *et al.,* 2020).

Market Potential

The local market alone in Zimbabwe has the potential to absorb several hundred thousand tonnes of finger millet a year. Currently the actual volumes produced and sold are small, but this is changing as consumer tastes adapt to the needs for a healthier, more wholesome diet. School and supplementary feeding programmes are also a strong driver of potential growth. To encourage more farmers to switch to small grains, in February 2020 the Zimbabwean government increased the price at which it buys pearl millet, sorghum and finger millet from farmers (Mambondiyani, 2020). Market based interventions that encourage smallholders to participate in the market may also improve the uptake of small grains.

This could be achieved through setting up platforms that may help in linking farmers to inputs and output markets (UNDP, 2018). It is also important for farmers to aggregate their produce and ensure regular supply in bulk quantity in order to compete with alternative grains like maize.

There is also considerable export market opportunity around finger millet, driven primarily by the rise in demand for gluten free foods. The global finger millet market is expected to reach US$14 billion by 2027 (Report Linker, 2020). Africa dominates global consumption of millets, approximately 40% of global millet consumption is held by African countries which include Niger, Mali, Nigeria, Burkina, and Sudan (Research and Markets, 2019).

Another longer term opportunity lies in malted finger millet as the basis for brewing. Barley is the major crops used at present, but its key shortcoming is that it is relatively high in gluten, meaning it cannot be consumed by the growing numbers of people around the world who are gluten intolerant. Finger millet presents the best single gluten-free alternative to this. This would require investments in both malting and marketing, but with a global market for barley of around 150 million MT/yr, only a small proportion of this would need to switch to finger millet to create a very substantial growth in demand.

Cultivation/ Domestication Potential

Finger millet is thought to have been domesticated at the beginning of the Iron Age in Africa and was introduced into India 3000 years ago before spreading to South-East Asia (Heuze et al., 2019). It is cultivated in warm temperate regions from Africa to Japan and Australia, and can tolerate an annual precipitation in the range of 290 - 4,290 mm. For good yields it requires irrigation if the rainfall is less than 530mm. Heavy rain at flowering is known to reduce seed set. The species thrives in areas with an annual temperature range of 11.1 - 27.4°C. It does well on soils ranging from rich loams to poor shallow upland soils and it can tolerate saline soils better than most cereals. Tolerates a pH in the range of 5.0 to 8.2 but it can tolerate very alkaline soils with a pH of up to 11.

Planting can be done by broadcasting or drilling method at an in-rows spacing of 7.5-30 cm. In some areas, furrows are opened 25-30 cm apart and seeds sown along with decomposed manure. Seed rate varies from 21-38 kg/ha. Sometimes seed is sown in nurseries and seedlings are transplanted after 3-4 weeks (Duke, 1983). Seedlings are sensitive to drought, but mature plants go dormant during short periods of drought and produce new tillers when conditions become favourable again. Weeds are a major problem in finger millet, the first two weeks after germination being critical. Several rounds of manual weeding are common, however it is labour intensive. Both green manures and artificial fertilisers can be applied to finger millet. Small amounts of zinc sulfate increase yields of both grain and straw. Seed inocculated with B. azotobacter increases yield.

Time from planting to flowering is 50 - 120 days; the complete crop cycle is 3 - 6 months. Flowering on individual inflorescences lasts for 8 - 10 days and proceeds from top to bottom on branches. The average finger millet grain yield under local practices of agriculture in tropical Africa is 0.25 - 1.5 tonnes per hectare however potential seed yield from improved cultivars is about 5 tonnes per hectare. Yield depends on variety and is directly related to duration, height and tillering capacity of type grown. Types with straight spikes give better yields than those with curved spikes (Fern, 2014). For food purposes the white-coloured grain preferred. The more bitter, dark-coloured grain is preferred for beer-making. For harvesting, crops are cut close to ground, stalks are allowed to wither for a day or two in field, and then bundled and stacked for about 2 months before threshing. To separate the grains, dried ear-heads are beaten with sticks, sheaves are trodden by bullocks or crushed by stone rollers. Separated grains are winnowed and cleaned.

4.10 Fadogia ancylantha

Latin: *Fadogia ancylantha*
Family: Rubiaceae
English: Makoni tea bush
Shona: Musvisvinwa
Ndebele:
Regions in Zimbabwe: Zambezi, Central, Save-Limpopo

Botanical Description

Fadogia ancylantha is a perennial plant with stems up to 180 cm long that can become woody. The stems grow out of a woody rootstock up to 2cm in diameter (Fern, 2014). The stems, usually between 2 and 6 in number, are branched or unbranched, smooth to lightly hairy and a yellowish-cream colour. The leaves are in pairs or whorls of 3, greyish-green, elliptic to rounded and often abruptly pointed at the tip. The inflorescences are shortly stalked, mostly 2–3 flowers, or flowers sometimes solitary. The flowers are usually distinctly curved, but sometimes straight (at least when dry), greenish-yellow, the tube usually greener, and the lobes green outside, whitish or pale yellow inside. The tube is from 2 – 3 cm long. The fruit are a dark grey-green, about 12 mm in diameter, round and 5-lobed when dry.

It occurs in grassland with scattered trees, high grassland, Acacia and Combretum wooded grassland as well as Brachystegia woodland and also in old cultivation, at elevations from 100 - 1,900 metres. It is common in Tropical Africa;, from Nigeria to Sudan and Uganda, south through eastern Africa to Zambia, Malawi, Zimbabwe and Mozambique (Fern, 2014). In Zimbabwe it is found in three ecological regions.

Traditional Uses

The Makoni tea bush is traditionally utilised as both food and medicine. Its most famous use (for which it is named) is as a herbal tea, made from the dried, unfermented leaves. The herbal tea is drunk both for its pleasant flavour and for its medicinal uses and health benefits. It has the reputation of being something of an overall health tonic, and is specifically consumed to boost the immune system, build stamina and treat abdominal pain, including menstrual pain, backache, chest pains, coughs and flu, and other ailments. Makoni tea has also been used to tone muscle and strengthen bones, and is often taken as an aphrodisiac (Odera, 2004). The name "Makoni" comes from an area of eastern Zimbabwe where the local King Makoni was said to have prescribed a daily dose of the tea to his soldiers to give them stamina and hasten their recovery time from wounds and injuries (Mandhiveyi 2016).

Another set of traditional uses relate to fertility and childbirth. On the one hand, the herbal tea is consumed as a treatment for fertility problems in women (Chara, 2021). On the other hand, pieces of Makoni tea bush root are used as a *zango,* a talisman that is tied around the waste by a woman to prevent conception (Sewani-Rusike 2010). A third use, relating to childbirth, involves blending elephant dung and Makoni tea leaves for topical application to the birth canal during the third trimester of pregnancy. This is said to ease childbirth by opening the birth canal during delivery (Mawoza *et al.,* 2019).

Other medicinal uses include the blending of ground root powders into porridge and administration by healers in Zimbabwe, as a treatment for madness (Gelfand et al., 1985). Elsewhere in Africa, dried and pounded leaves are decocted in water and the concoction is used to treat microbial disease such as ring worms and purulent rashes in Burundi, (Ngezahayo et al., 2015). In Malawi the tea is consumed for the management of diabetes, hypertension, gastrointestinal disorders and pneumonia.

In Zimbabwe, the nectar produced by *F. ancylantha* flowers is sweet and sucked by children as they herd cattle. Roots are chewed and then used as a toothbrush which helps stop bleeding from the gum (Ruffo *et al.,* 2002).

Commercial History

The commercial development of Makoni tea goes back to the mid 1990s, when members of the Makoni community in eastern Zimbabwe approached the local NGO SAFIRE and asked for assistance on developing the tea as a commercial product for the benefit of the community. SAFIRE in turn linked

them up to the company Tulimara and Makoni tea was launched on to the Zimbabwean market shortly afterwards in tea bag form. Later, SAFIRE facilitated the establishment of the Makoni Indigenous Tea Producers' Association to represent the interests of the tea harvesters, and also supported the development of tea processing facilities at community level to enable community members to progress further up the value chain (Odera, 2004). Since then, Makoni tea has become an established product on the local market in Zimbabwe, and is often exported by informal traders to meet demand from Zimbabweans living in neighbouring countries (Kadungure, 2015). There are several brands selling the tea and it is often found in supermarkets.

Potential Commercial Uses

Many of the health benefits of Makoni tea have been validated by scientific research. Researchers at the University of Zimbabwe undertook a comprehensive review of the phenolic compounds in the tea (Bhebhe *et al.,* 2015), looking at the total phenolic content, tannin content and antioxidant activity exhibited through radical scavenging, reducing power, and inhibition of phospholipid peroxidation. They also compared it to the well-known South African Rooibos herbal tea (*Aspalathus linearis*) (Rooibos). They found that, although the total phenolic content of Makoni tea is lower than for Rooibos, its antioxidant free radical scavenging activity was on par with Rooibos, with the added advantage of having a lower tannin level (which can be an issue, as tannins inhibit the absorption of minerals such as iron). In terms of inhibiting phospholipid peroxidation, Makoni tea actually outperforms Rooibos, suggesting strong activity in the prevention of diseases (such as cancer) caused by lipid peroxidation. Other researchers have shown that *Fadogia ancylantha* has significant potential in the treatment of diabetes and other degenerative diseases caused by oxidative stress (Nyirenda *et al.,* 2012), and that it has potential hepatoprotective effects and may be effective in protecting against ethanol-induced liver damage (Tiya *et al.,* 2019).

The first and most obvious area for expanded commercial use of Makoni tea bush is building on these credentials as a herbal tea. Unfortunately the tea does not have regulatory approval for sale in many export markets, but there are significant local and regional markets into which it is not currently supplied. Value-added products include 'kombucha' (made from microbial fermentation of tea to aid flavour and nutritional value) and green tea. A Makoni tea extract could be used as a flavour in alcoholic beverages (e.g. craft gin), with fruit combinations in

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Makoni tea: Zimbabwe's Rooibos?

Indigenous species has huge potential for export

BY WALLACE MAWIRE

soft drinks, functional drinks and flavoured waters (UNCTAD, 2016). Speciality teas can also be made by blending Makoni tea and other teas (e.g. *L. javanica*) together with medicinal herbs. Makoni tea extracts also have potential applications in breads and baked goods, frozen dairy desserts, candy and seasonings.

Building on its traditional medicinal use, there are multiple other presentational forms for Makoni tea as a herbal medicine. Syrups, tablets, capsules, topical ointments, creams and lotions are all examples of other potential herbal medicine products that could be developed and marketed based around Makoni. Its reputation as a stamina builder and aphrodisiac also suggests potential applications to enhance sexual performance.

Market Potential

The global herbal tea market is booming, growing at 6% year on year and is currently valued at over US$5 billion/yr (Allied Market Research, 2020). People are moving away from caffeinated tea (the cured or fresh leaf of *Camellia sinensis*) and into caffeine-free alternatives. Consumer demand for natural and herbal medicinal formulations is rising, and herbal tea is an excellent and highly accessible format for the consumption and use of traditional and natural remedies. Asia-Pacific and Europe are the most prominent markets for herbal teas due to historically high levels of tea consumption in those regions (Allied Market Research, 2020), but the North American market is showing especially fast growth at the moment. Herbal teas are currently more often being marketed as functional blends with particular uses, for example organic India's "Balance" tea which is meant to support digestive health (Good eggs, 2021). This functional focus is catching on in markets like Brazil which are well known for their coffee consumption (Culliney, 2019).

The herbal tea market has also been boosted by the global COVID-19 pandemic, with consumers around the world turning to herbal teas to help build immunity. Interestingly, Makoni tea was specifically mentioned in this regard by more than half of the interviewees when researchers asked South Africans what they had added to their diet to help fight off COVID-19 (Pieroni *et al.,* 2020). This has also been reflected in Zimbabwe, where consumers have turned en masse to herbal teas like Zumbani (Lippia javanica) to help ward off the disease (Moyo, 2021).

Domestically it is estimated that Zimbabweans consume up to 500 MT herbal tea/yr, of which nearly 80% is imported (Bio-Innovation Zimbabwe, 2017). As a comparison, the Rooibos tea industry in South Africa employs more than 5,000 people, with production volumes of up to 20,000 MT/yr and an industry value of at least US$100 million/yr. Interestingly, despite being an important export product for South Africa, more than 50% of the Rooibos sales per annum are to local consumers.

The world herbal medicine market, against the backdrop of a global pandemic, has undergone a surge in growth in the last year. Currently estimated at USD 148 billion/yr in 2020, it is projected to reach USD 219 billion by 2026 (Market Watch, 2021). In China, 40% of all pharmaceutical sales are from herbal medicines, and the Chinese herbal medicine industry alone is valued at US$36 billion/yr.

Cultivation/ Domestication Potential

With the high market potential of *F. ancylantha,* cultivation of this species is necessary to ease pressure on the wild harvesting process. Cultivation or domestication also gives competitive advantages to local producers and creates new local value-adding opportunities. There is however almost no information currently available on production guidelines of this species in literature, and it is an unexplored area of research.

In the wild, a Makoni tea bush yields approximately 20 kgs of useable leaf material per year. Because the bushes are currently wild-harvested, rather than cultivated, average yields in producing areas at present do not exceed 280 kg per hectare (i.e. the yield from 14 bushes). However, with cultivation, yields would be expected to go up dramatically. Although a farmer could potentially produce as much as 32 tonnes/ha/yr (spacing the shrubs at 2.5 m intervals, giving 1,600 shrubs per ha), a more realistic expectation would be that the bushes are planted as a hedge around the edge of a field. This could reasonably be expected to result in bushes being planted at an average overall density of some 200 per hectare, yielding 4 tonnes of wet tea/ha.

4.11 Harpagophytum zeyherii

Latin: *Harpagophytum zeyheri*
Family: Pedaliaceae
English: Devil's Claw, Grapple
Shona:
Ndebele: Inkunzane enkulu
Regions in Zimbabwe: Kalahari, Save-Limpopo

Botanical Description

Harpagophytum zeyheri is a prostrate, mat-forming perennial herb which is often considered as a weed. It is a herbaceous plant that can grow up to 1,5 m in length. The plant has creeping annual stems of up to 2 m long, spreading from a tuberous, fleshy root-stock. The stems are covered with glandular hairs which exude a slimy, sticky sap. The roots have a strong central taproot and secondary root tubers (storage roots) branching off horizontally. The main roots can grow up to 50 cm in length and the secondary roots up to 25 cm long. They are found at depths of up to 2 m below the surface. The plant can store up to 90% water in these storage roots.

Although the name Devil's Claw comes from the spiky, claw-shaped fruit, the parts of the plant used for its medicinal value are the tubers, shaped like elongated sweet potatoes. Flowers and leaves only appear during the rainy season. The tubular flowers are dark violet with a yellow and white throat, and the large, heart-shaped leaves are grey-green in colour. From the flowers grow the woody, sharply curved, sticky, barbed fruit. The characteristic fruit have numerous long arms with sharp, hooked thorns, as well as two straight thorns on the upper surface.

There are two species of *Harpogophytum* that share the name "Devil's Claw" and from both of which the tubers are harvested for medicinal use. *Harpagophytum procumbens* is found in the west of the range, in Namibia, Botswana, South Africa, and Angola. H. zeyheri is found in the east of the range, Zambia, Zimbabwe, and Mozambique. The two species overlap at the edges. They are differentiated visually by the shape of the leaves, and also by the length of the arms of the fruit; the arms of *H. procumbens* fruit are longer than the width of the fruit, and the arms of *H. zeyheri* fruit are shorter than the width of the fruit (Engels and Brinckmann, 2018). In Zimbabwe Devil's Claw is only available in the Kalahari and Save-Limpopo ecological regions.

Traditional Uses

Although the Devil's Claw root tuber is best-known as a traditional medicine of the San people in the Kalahari region, it has been used medicinally by local communities throughout its range. Traditional uses of the tuber have included being consumed as a laxative, as a treatment for arthritis and blood conditions, headache, fever, indigestion, pain after childbirth, and malaria. It is considered an analgesic, and it has been used topically to treat boils, sprains, sores, and to ease childbirth. Devil's Claw preparations also have folk uses in diabetes, gout, and tuberculosis, as a mouthwash for bleeding gums, and for hypertension, menstrual cramps, peptic ulcers, snakebites, lumbago (lower back pain), and wound and burn healing. Apart from medicinal use, the leaves are also sometimes used as a natural alternative to soap, consistent with other species in the sesame family (Pedaliaceae).

Commercial History

The commercial history of *H. zeyheri* is interwined with the history of *H. procumbens*. *H. procumbens* was first described by botanists in 1822, and *H. zeyheri* shortly afterwards. Both were known to have traditional medicinal use, but it was the efforts of one German farmer in Namibia that first brought the medicinal value of *H. procumbens* to more widespread attention. Initially marketing a herbal tea on the local market in Namibia, in 1957 he sent samples to a university in Germany where they were first studied and described as a treatment for rheumatism, arthritis and other ailments. In 1962, a Namibian company started exporting Devil's

Claw-tubers in larger quantities to a German herbal tea manufacturer. Interest grew in the product and a German Commission E monograph was published in 1989 for Devil's Claw root tuber, prepared as a herbal tea infusion or equivalent preparations, for loss of appetite, dyspepsia, and as supportive therapy of degenerative disorders of the locomotor system. In 1990, French health authorities approved the oral and topical use of Devil's Claw root tuber as a traditional herbal medicine used for symptomatic treatment of minor painful articular condition (Engels and Brinckmann, 2018). In 1994 it was approved by the European Directorate for the Quality of Medicines.

Up to the early 2000s, only *H. procumbens* was technically approved for use in Europe, although it was discovered that many suppliers were blending (perhaps inadvertently) *H. procumbens* and *H. zeyheri,* and in 2002 H. zeyheri was added to the European monograph. Today the marketing of Devil's Claw in Europe is governed by monographs of the European Medicines Agency dating from 2016, in which both species are approved for use in the European Union.

Most Devil's Claw export takes place in the form of dried, sliced tubers, which are sold to extract manufacturing companies, predominantly in Europe. Namibia is the major exporter, although smaller amounts are also exported from Botswana, Angola, Zambia and Zimbabwe (Stewart and Cole, 2005). In 2002, the peak year of export, 1018 tonnes of dried tubers were exported from southern Africa, representing the harvest of millions of plants (Stewart and Cole, 2005). Devil's Claw is also sold locally on traditional medicinal plant markets in Namibia, South Africa and elsewhere in the region.

It is the iridoid glycoside, harpagoside, present in both *H. procumbens* and *H. zeyheri,* that has been found to be effective in the treatment of degenerative rheumatoid arthritis, osteoarthritis, tendonitis, kidney inflammation, and heart disease. Although the chemical composition of non-harpagoside constituents vary between the two species, their harpagoside content is comparable (Kondamudi *et al.,* 2016), and they are therefore considered essentially interchangeable for medicinal use.

Potential Commercial Uses

The primary commercial use of Devil's Claw will continue to be in herbal medicine, in the form of tablets, tinctures and herbal teas, to relieve pain in patients suffering from rheumatic and arthritic disorders (Avato and Argentieri, 2019). In addition, Devil's Claw root may be used as a dietary supplement (Engels and Brinckmann, 2018) or blended into health food preparations as functional ingredients. Sports nutrition would be an obvious potential market, incorporating Devil's Claw into a range of existing products to prevent and relieve inflammation, especially for long-distance or endurance sports.

A second key, and presently wholly unexplored, area of commercial potential lies in the skincare market. Cosmetics manufacturers are increasingly looking to incorporate anti-inflammatory ingredients into their products to help offset localised redness, swelling and irritation on the skin. Devil's claw has proven efficacy in terms of topical application to reduce inflammation, and has the added advantage of being a natural, herbal ingredient, with strong potential appeal to skincare companies.

A third potentially interesting market is veterinary medicine. Devil's Claw is already used for the treatment of inflammatory symptoms and degenerative disorders in horses, where it is especially valued by race horse owners. Livestock also respond well to Devil's Claw, but this is a smaller market. The main untapped opportunity lies in the creation of herbal products for ageing pets, especially dogs and cats, for which sizeable markets exist in many western countries.

Market Potential

The global herbal medicine market is enormous and rapidly growing. Currently projected at USD 148 billion in 2020, it is projected to reach USD 219 billion by 2026, (Market Watch, 2021). Devil's Claw is well-known in a small sub-sector of this market (principally Germany, the US and a few western European nations), but is almost completely unknown in many other markets, especially Asia and Latin America. In China, 40% of all pharmaceutical sales are from herbal medicines, and the herbal medicine industry is estimated at US$36 billion/yr. Devil's Claw has not yet been registered for sale in China, but it could well find a substantial market there once it has been through the regulatory approval processes. Opportunities in the African regional market for Devil's Claw should also not be ignored.

Skincare is another very substantial market, estimated at USD 150 billion in 2020 and growing to USD 190 billion in 2025 (Statista 2020). Of this the fastest growth segment is in organic skincare, as consumers move away from petrochemicals and look to use natural ingredients instead. Limiting the visual impacts of ageing is the primary motivation for most consumers, and in this regard products that are associated with preventing or treating age-related disorders (as is the case with Devil's Claw) are projected to do especially well in coming years.

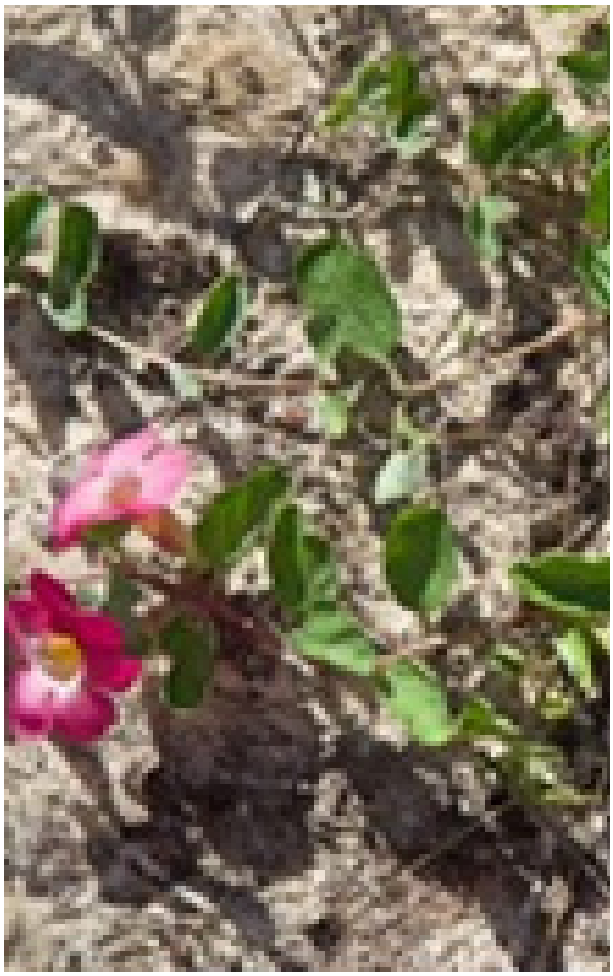
Veterinary medicine and petcare are also substantial markets. The US pet industry alone is valued at nearly USD 100 billion/yr. Incorporation of Devil's Claw into existing petfood formulations or as a separate herbal remedy would seem very feasible as a possible route into this market.

Cultivation/ Domestication Potential

The nature of *H. zeyheri* wild harvesting process has raised sustainability concerns over the past year. However, Devil's Claw cultivation has been ongoing in South Africa and Namibia since 2002 (Engels and Brinckmann, 2018). The species is propagated by seeds or secondary tubers. The seeds are planted early summer season, and the young/secondary tubers are usually retrieved in the autumn. Planting of Devil's Claw seed requires loosening of the top quarter of soil with a rake. If the soil is too compact, preparation for planting by digging and turning the soil to a depth of approximately 8 cm is required. The seeds should be scattered evenly over the prepared beds or should be sown in a furrow of 20 cm deep and 60 cm wide. After sowing, the seeds can be raked up slightly and covered with a thin layer of soil.

The seeds should be irrigated daily with a fine mist sprayer, keeping the bed evenly moist until the seedlings emerge. After emergence, irrigation should be applied every second day, as temperatures drop, the frequency can be extended. Frequency of irrigation depends on the temperature and soil. Once the plants are showing four to five leaves and are well established, further irrigation once or twice a week will be sufficient. There are no major pests and diseases affecting the Devil's Claw, however, very rarely it is disturbed by aphids and powdery mildew.

The only pests of concern are animals feeding on the tubers, e.g. porcupines and antelope such as duiker and steenbok. Birds are attracted to the freshly seeded wild flower. In areas that are small, bird netting can be used. Devil's Claw takes three to four years to reach maturity and the matured plant is very hardy. Harvesting takes place during the rainy season, from November to June/July each year (DAFF, 2015).



4.12 *Hyphaene petersiana/coriacea*

Latin: *Hyphaene petersiana /coriacea*
Family: Arecaceae
English: Ilala
Shona: Murara
Ndebele: Ilala
Regions in Zimbabwe: Zambezi, Kalahari, SaveLimpopo

Botanical Description

Hyphaene is a genus of palms with some 10 species spread from Africa through the Middle East to India. In Zimbabwe there are two species within the genus, *Hyphaene petersiana* (called the Northern Ilala) and *Hyphaene coriacea* (called the Southern Ilala). They are very similar to each other and are often described interchangeably. Not surprisingly they have been the subject of considerable taxonomic debate. The distinctions relate to fruit shape as well as tree size, with *H. coriacea* (found in the south-east of the country) having more pear-shaped fruit and smaller trees that grow more readily from sucker. *H. petersiana* (found generally, but not exclusively, in the north-west of the country) has rounder fruit and the trees are non-suckering and taller (Hyde et al., 2018). All other features of these two species are essentially the same.

The ilala palm is an erect, usually single-stemmed tree. Stems are rarely suckering to form clumps. It grows to an average height of 18 m (Mutete *et al.,* 2018). Leaves are crowded on top of the stem, fan-shaped, up to 2.5 m long including the petiole. The petiole is armed with recurved thorns. Trunks are straight with prominent, discontinuous, large leaf scars, and are unarmed. Leaves are spirally arranged, costa-palmate (fan-like, with a midrib), blue-grey. The petiole margins have distinctive teeth ± 10 mm apart, 10 mm long, forward pointing. The leaflets are 2-ranked, erect, evenly spaced, with the central fold down. The lamina are up to 400 x 35 mm. The tips are simple, acute, smooth and straight. The leaf bases are persistent, scale-like, split, without an inner auricle, woody. Inflorescence between the leaves, branched, pendulous, 0.4-1.0 m long. Plants are dioecious (separate male and female trees) (Glen, 2004). Male inflorescence are slenderer and more branched than female.

The female flowers can occur in large sprays which develop into branched trusses of frtui. The distinctive fruit are brown, fibrous outer (edible) pith, 4 to 6 cm in diameter, and contain a hard, white kernel known as "vegetable ivory". When young, the vegetable ivory is soft and edible, hardening up to a dense ivory-like substance as it matures.

Ilala palms occur in dry sandy lowland areas, often away from rivers (Ken, 2014). In Zimbabwe they are found in 3 ecological regions.

Traditional Uses

Ilala palms have been utilized by rural communities in Zimbabwe for a long time. In the Sengwe communal land in the south-east of the country, inhabited by people of both Shangaan and Ndebele ethnic origin, ilala palms are a major source of income to the local communities (Foote *et al.,* 2003). A sap is tapped from the stems of the trees and used to make an alcoholic wine (called *Njemane*), while the leaves are used to make baskets and handicrafts and the dry petioles are used for furniture (doors and chairs) (Sola et al., 2006). There is an obvious and inherent danger in the tapping of ilala palms for sap in that the tapping has the potential to severely reduce the growth of the tree. Over time a complex set of local rules and regulations have been established to regulate the use of the plant for sap tapping to prevent over-harvesting.

Palm wine production is also common in other African countries where the ilala is found. It is produced by cutting away the apical meristem, making an incision and inserting a leaf stalk as a spout. The sap oozes down this and is collected in small gourds hung below. A plaited straw hat is placed over the tip of the palm to keep it moist and protect it. The cloudy, whitish sap is then fermented and drunk. Having a very short shelf-life (often of only one day), the palm wine is often saved for special occasions (weddings, funerals etc) and is not consumed on a regular basis.

The outer pith of the palm fruit is edible, with a somewhat gingery flavour. Generally the fruit are eaten by children while out herding livestock but are rarely brought home for consumption there, not being considered tasty enough to warrant eating as part of a meal. The liquid or "milk" from the unripe seed is often drunk, like coconut milk. In some areas there is a tradition of carving the hardened nut kernel or vegetable ivory into ornaments.

Commercial History

Palm wine has been produced and marketed locally by communities across Africa. One recent study in southern Mozambique showed tappers earning

up to USD 2,700/yr from tapping and marketing palm wine (Martins and Shackleton, 2018). However, issues of short shelf-life and limited appeal have meant the wine is rarely sold beyond the boundaries of its harvester communities. One notable exception has been a company in Ghana who have transformed palm wine into a commercial success and exported it to customers in the US and Europe (Iwuoha, 2014). This has not been repeated elsewhere and it is not known if the company is still in business.

There has been more commercial success with basket-making from ilala palm fronds. This is seen as a highly developed and valued art form. There are many women basket-makers in Zimbabwe who have become internationally-acclaimed artists, especially from the Binga area of north-west Zimbabwe. In the 1980s, the Binga craft centre was established, funded by the Danish government, and became a central part of the Zimbabwean handicrafts industry. Market linkages were enhanced by the establishment of the Government-owned National Handicrafts Distribution and Marketing Centre. At one time the Binga Crafts Centre was exporting several thousand baskets a year, and was supplied by more than 4,000 women from 34 different weaving clubs across Binga district.

Potential Commercial Uses

Given the explosive growth of the craft alcoholic beverage market in recent years, there would seem to be clear commercial potential to develop the ilala palm sap. Globally there are many different palm species used to make palm wine, and there has been significant investment in technologies to improve the harvesting, processing and storage of the sap. The obvious link for the ilala palm wine would be with craft rum, integrating the palm wine into a rum beverage to create a unique marketing story. Small batch distillation runs, to make a high-end product with a rarity value that would justify a high price point, could do well for ilala harvesters. Multiple value-addition opportunities would also exist around the beverage, with potential for incorporating it into cocktails, liqueurs, spirit coolers and other products. Further links into the tourism industry could also be developed, mimicking the success of the South African brand Amarula. Today, the "Amarula Lapa", a hospitality marketing centre educating visitors on the production process and associated back story for Amarula and situated on the edge of Kruger National Park, is a major tourist attraction for international visitors.

Basketry is another opportunity with significant commercial potential for ilala harvesters. Ilala palm fronds are said to make some of the finest quality baskets, and Zimbabwean basket-weavers are already seen as artists of exceptional talent. Developing this further into a major industry would seem entirely feasible. Again, links with the tourism industry provide opportunities to upsell, but the biggest market would be in terms of industrialised production for export. As an addition to this, the use of the vegetable ivory to hand make complementary items (e.g. buttons to go on high-end clothing) could create a valuable secondary revenue stream.

Market Potential

The global craft spirits market is growing at a remarkable 33% a year and is projected to reach USD 80 billion/yr by 2025 (Grand View Research 2020). The demand is underpinned by growing consum-

er interest in premium and authentic drinks with unique flavours and strong marketing stories. The largest share of consumers is made up of people born between 1980 and 2000 (the so-called millennials) who have a markedly different taste to their preceding generation. Millennials prefer unconventional and experimental beverages, and are often as concerned with the story behind their conception and manufacture as they are with the flavour and ingredients used. Craft spirit demand is led by whiskey, but closely followed with gin, vodka and rum. Of these, rum offers the best opportunity for incorporating ilala palm wine into a craft spirit.

Rum is made from sugar cane, heavily flavoured with different spices, fruits and other botanicals. It is seen as a tropical drink, and is often the drink most consumed by western holidaymakers in tropical locations. The global craft rum market was valued at over US$1 billion/yr in 2019 and is rapidly growing (Vision Research 2020), with many observers predicting that craft rum will be the next explosive trend in the beverage industry (after craft gin from 2010 to 2020).

Basket-weaving fits into several different market categories, each with their own potential. It is first and foremost seen as a handicraft, meaning a product that is hand-made rather than machine-made, and that reflects the cultures and traditions of the maker. The global handicrafts market is huge, reaching USD 530 billion in 2017 and projected to grow to USD 985 billion by 2023. The USA is the single biggest handicraft market, and department stores remain the single largest market outlet (although online sales are catching up rapidly).

The second, and perhaps ultimately more predictable, market opportunity lies around sustainable (or "green") packaging. This is another vast and rapidly evolving market. As consumers are increasingly shying away from single use plastic packaging, the hunt is on for alternatives. The food and beverage industry are turning to degradable, recyclable and natural packaging materials, and other industries (e.g. fashion, cosmetics and toiletries) are starting to follow suit. Valued at USD 260 billion in 2019, the global market for green packaging is predicted to rise to USD 400 billion by 2025. Handmade ilala palm baskets would make a beautiful packaging material for high end products.

A holistic approach to marketing ilala palm products might ultimately see a craft ilala palm rum bottle, wrapped in a handmade ilala basket and capped with a hand-carved ilala vegetable ivory bottle top.

Cultivation/ Domestication Potential

Large-scale production of ilala palm products would certainly require domestication and intensive cultivation. Ilala palms may be grown from seeds, however Coates Palgrave (2002) noted that the seeds are difficult to germinate. The seeds of *H. petersiana exhibit dormancy* (Sullivan et al., 1995), and according to Baskin and Baskin (2013), dormancy is a common feature in the *Aceraceae* family, which may affect ex-situ conservation. A previous study observed the effects of different seed pre-treatment methods on their potential to release the dormancy of *H. petersiana* seeds (Mutete *et al.,* 2019). No germination was observed for seeds treated with sulphuric acid. Water soaking for 12 hours proved to be an efficient method of releasing dormancy (Mutete *et al.,* 2019). Sowing the seed is done directly onto the ground as these plants transplant with difficulty.

Palms prefer growing in alluvial sands. They grow slowly, but need much space for expansion. Moll indicates that ilala palms grow at the rate of about one new leaf a year. In view of the above, it is not surprising that ilala palms are so rarely seen in gardens that their pests and diseases are unknown. Untreated fruits kept for decorative purposes may be attacked by cigarette beetles and other similar insects. The usual treatments (freezing, fumigation, insecticide spray) are adequate to control this provided that the damage is noticed in time.

4.13 Lippia javanica

Latin: *Lippia javanica*
Family: Verbenaceae
English: Fever tea, Lemon bush
Shona: Zumbani
Ndebele: Umsuzwane
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

Lippia javanica is an erect, woody shrub in the Verbena (*Verbenaceae*) family. It is intensely aromatic, being rich in volatile oils. Usually around 1 – 2 m high (although it can grow up to 4.5 m), it has upright or spreading brownish stems with short, off-white hairs and small glands. The hairy leaves are opposite or in whorls of 3, lanceolate to oblong in shape, toothed along the margin and with noticeable veins sunken above (van Wyk & Gericke, 2000). When crushed, the leaves give off a strong lemon-like smell. Flowers occur in dense round, small clusters and are creamy-white in colour.

Lippia javanica occurs naturally in central, eastern, and southern Africa and has also been recorded in the tropical Indian subcontinent (Narzary & Basumatary, 2015; Kumar and Dash, 2012; Shahriar *et al.,* 2014). It occurs in a wide range of altitudes (0–2350m above sea level) and vegetation types, including woodlands and wooded grasslands, scrub bushland, and grassy rocky kopjes, in riverine vegetation, and on margins of swampy ground, sometimes on termite mounds, in montane grasslands, and on evergreen forest margins, also in disturbed ground beside roads, forest clearings, plantations, and cultivated land (Verdcourt, 1992). It is highly adaptable to different climatic, soil, and vegetation conditions. In Zimbabwe it is found in all ecological regions.

Traditional Uses

Lippia javanica, commonly known in Zimbabwe as Zumbani, is popular as a herbal tea, particularly in Southern Africa (Bhebhe *et al.,* 2016; Shikanga et al., 2010). The tea is prepared by steeping fresh or dried leaves, stems, or twigs in boiling water and letting them stand for two to five minutes to release flavour, with or without milk and sugar added according to taste. The tea has a pleasant lemonish-vanilla aroma. It is often consumed as a medicinal tea, used to prevent a treat a range of common ailments including colds, coughs, influenza and related chest ailments. These medicinal uses give it the English name of "Fever tea", as in a remedy taken to address a high fever. *L. javanica* tea is also appreciated throughout its distributional range as a general health tonic and also because it is naturally caffeine-free and has a calming and relaxing effect (Shikanga *et al.,* 2010).

The medicinal uses of Zumbani are not confined to the tea. In many areas root decoctions are also consumed to treat blocked nose, chest pain, cough, earache, fatigue, fever, influenza, headache, runny nose, sleepless nights, sore throat, tiredness, and tonsillitis (Davids *et al.,* 2014). In Zimbabwe, a leaf ointment is rubbed on the chest and abdomen as a remedy for pneumonia and the body is washed with a leaf decoction as a remedy for shortness of breath or dyspnoea (Gelfand *et al.,* 1985). Leaf and root decoctions are also used as remedies of the digestive system diseases such as cholera, diarrhoea, and dysentery (Bruschi *et al.,* 2011).

Another common traditional use associated with *L. javanica* is as an insect repellant (Gelfand *et al.,* 1985; Lukwa *et al.,* 2009; Samie *et al.,* 2005). Leaf decoctions are used to wash or steam body parts infested with lice (Mahachi, 2013), whole plants or leaves are burnt to repel mosquitoes and lice (Luk-

wa *et al.,* 1998, 2009; Moeng, 2010) and also used to get rid of ticks and other ectoparasites (Nyahangare *et al.,* 2012, 2015). Leaf infusions of *L. javanica* are used to treat skin disorders, such as boils, chicken pox, febrile rashes, heat rashes, measles, scabies, scratches, and stings (Hutchings *et al.,* 1996; Mahachi, 2013). In Zimbabwe, root ashes of *L. javanica* mixed with fat are applied to the skin of a patient with scabies (Gelfand *et al.,* 1985).

There are also many spiritual uses associated with Zumbani, as a good luck charm, to ward off evil spirits, to protect from dogs and crocodiles, and to prevent bad luck when exposed to a corpse. A mixture of leaves and roots are often used to clean tools and hands before and after funerals. The leaves are often burned simply to create a pleasant aroma around the house.

Commercial History

As a herbal tea, *Lippia javanica* has been packaged and marketed in Zimbabwe, Botswana and South Africa for at least 25 years. Initially in Zimbabwe it was the pioneering company Tulimara who began selling Zumbani tea, but today the tea is marketed by a range of different herbal tea brands. Consumption levels have spiked with the COVID-19 pandemic, and the tea is often found selling in informal markets as well as on supermarket shelves. Efforts have been made to find export markets for the tea, but these have been thwarted by the fact that it does not have regulatory approval for sale in many international markets (including the EU, North America, China), and would need to undergo an extensive (and expensive) set of toxicological and associated trials in order to meet these requirements.

In parallel to its commercial development as a tea, *L. javanica* has also been commercialised in Kenya (Musila *et al.,* 2004) and South Africa (Maharaj *et al.,* 2008) for essential oil production for the mosquito-repellent candles and perfume industry. Based on these findings, the Council for Scientific and Industrial Research (CSIR), South Africa, signed a benefit sharing agreement with traditional healers allowing for the commercial cultivation of *L. javanica* aimed at establishing an indigenous oil industry for rural development and large-scale production of anti-mosquito candles and other insect repellents (Maharaj *et al.,* 2008). These candles are currently marketed in South Africa under the brand Fever Tree.

Potential commercial uses

The current commercial use of Zumbani as a herbal tea provides many opportunities for further value-addition. The health and medicinal properties of the tea are well-documented and its flavour is highly appealing. Zumbani it lends itself well to many of the spin-off products often derived from tea including 'kombucha' (made from microbial fermentation of tea to aid flavour and nutritional value) and green tea. A Zumbani tea extract could be used as a flavour in alcoholic beverages (e.g. craft gin), with fruit combinations in soft drinks, functional drinks and flavoured waters (UNCTAD, 2016). Speciality teas can also be made by blending L. javanica and other teas together with medicinal herbs. Zumbani tea extracts also have potential applications in breads and baked goods, frozen dairy desserts, candy and seasonings.

Building on its traditional medicinal use, there are multiple other presentational forms for Zumbani as a herbal medicine. A Zimbabwean university recently developed Zumbani throat lozenges and cough drops, specifically aimed at helping to boost immunity in the face of the COVID-19 pandemic. Syrups, tablets, capsules, topical ointments, creams and lotions are all examples of other potential herbal medicine products that could be developed and marketed based around Zumbani.

There is already small-scale production of the essential oil of *L. javanica* in South Africa and Kenya as an insect-repellent. However, there is scope for much wider adoption and promotion of the oil for pesticidal use. Researchers have shown that topical applications of L. javanica provide 100% protection against the malarial mosquito Anopholes aegypti for 8 hours (Lukwa et al, 2009). The demand for natural repellents as an alternative to synthetic and poten-

tially harmful chemicals is growing. Future research should focus on more comprehensive chemical characterization of both crude and pure extracts of L.javanica for insect repellent and pest control.

Market potential

Globally, the US$5 billion/yr herbal tea market continues to show robust growth across all markets (estimated at 6% per annum). Consumer demand for natural and herbal medicinal formulations is rising, and herbal tea is an excellent and highly accessible format for the consumption and use of traditional and natural remedies. Asia-Pacific and Europe are the most prominent markets for herbal teas due to historically high levels of tea consumption in those regions (Allied Market Research, 2020), but the North American market is showing especially fast growth at the moment. New herbal tea brands are constantly appearing and there is also an increasing demand for Ready-to-Drink beverages on a large scale (Future Market Insights, 2016). Note however that, in order to access these different markets, *L. javanica* would need to undergo comprehensive regulatory approval process.

Domestically it is estimated that Zimbabweans consume up to 500 MT herbal tea/yr, of which nearly 80% is imported (Bio-Innovation Zimbabwe, 2017). As a comparison, the Rooibos tea industry in South Africa employs more than 5,000 people, with production volumes of up to 20,000 MT/yr and an industry value of at least US$100 million/yr. Interestingly, despite being an important export product for South Africa, more than 50% of the Rooibos sales per annum are to local consumers.

The world herbal medicine market, against the backdrop of a global pandemic, has undergone a surge in growth in the last year. Currently estimated at USD 148 billion/yr in 2020, it is projected to reach USD 219 billion by 2026 (Market Watch, 2021). In China, 40% of all pharmaceutical sales are from herbal medicines, and the Chinese herbal medicine industry alone is valued at US$36 billion/yr.

The essential oils market also has potential to absorb significant volumes of L. javanica raw material. The global essential oils market size was estimated at US$7 Billion in 2019 and is expected to reach US$14.1 Billion by 2026 (Globe Newswire, 2020). The market for insecticides, while heavily dominated by organophosphates, is showing significant appetite for botanically-derived products. Currently the total market value is USD 15 billion/yr (Mordor Intelligence 2021), of which bio-insecticides represent only a small, but by far the most dynamic, fraction at present. Asia-Pacific is both the biggest and fastest-growing market for insecticides.

Cultivation potential

Cultivation of *L. javanica* is a solution to the sustainability problems associated with harvesting of the species from the wild, and this option is also necessary for establishing commercial scale medicinal production and processing and trade enterprises. *L.javanica* grows easily from seeds and from cuttings. It grows relatively fast and prefers sunny areas. Fever tea tree is not very particular and seems to do well in most soil types. Seeds are tiny nuts and brown in colour and are collected from fruits at onset of natural dispersion. After harvesting, fruits are placed in open trays at room temperature to dry and open to release the seeds. Seeds are separated from the fruits by light threshing and hand sorting. It is known to colonise disturbed areas, making it a pioneer plant. *Lippia javanica* is very hardy and can grow under difficult circumstances, requiring little maintenance. It responds well to fertigation.

4.14 Myrothamnus flabellifolius

Latin: *Myrothamnus flabellifolius*
Family: Myrothamnaceae
English: Resurrection bush
Shona: Mufandichimuka
Ndebele: Umafavuke
Regions found in Zimbabwe: Zambezi, Central

Botanical Description

Myrothamnus flabellifolius (often incorrectly referred to as *M. flabellifolia*) is a unique plant, one of only two species in the family Myrothamnaceae, and unique because it is the only woody resurrection plant in the world (Moore et al, 2007). It is a small, resinous shrublet, which grows from 0.2 - 1.2 m in height. It is only ever found growing on rocky outcrops, where it occurs singly or in colonies with extensive root systems that extend into crevices of the rock where soil deposits have accumulated. Its roots are able to intercept water draining into these hollows after rainfall, thereby initiating re-hydration.

Its leaves are opposite, folding fan-like, with broad tips and a wavy margin, with the stalk sheathing at the base to form a joint with the blade. The leaves of the resurrection bush shrink and appear to be dead in the dry season, but miraculously turn green within a few minutes after exposure to water. The habit persists, even when the stems have been picked some time ago. The Shona name (Mufandichimuka), meaning literally "die and come back to life", refers to this remarkable property. The stem is rigid, much branched and aromatic. The plant is dioecious, meaning the male and female reproductive organs are borne on separate individuals of the same species. The tiny flowers, without calyx or corolla, are borne in small catkin-like inflorescences usually occurring on short lateral branches. The male flowers, which consist of three to six stamens with reddish anthers that dehisce (split open) longitudinally, produce abundant amounts of yellow, tricolpate (having three openings) pollen grains at maturity. Flowering occurs from September to November. The fruits are three-lobed, leathery, dehiscent capsules, which are slightly larger than the carpels at anthesis (Kondlo, 2013).

It usually forms large stands in shallow soil on sunny rocky hills or along cracks and crevices in rocks (African Plant Database, 2012). In Zimbabwe it is found in only 2 ecological regions, mainly areas characterised by granitic domed inselbergs.

Traditional Uses

The resurrection bush is an important medicinal plant in southern Africa with a multitude of traditional medicinal uses. The main mode of delivery is as a hot beverage, boiling the leaves and twigs in water and then drinking the resultant tea. This is consumed as a cold remedy, also for influenza, mastitis, backache, kidney disorders, haemorrhoids, abdominal pain and to lower blood pressure. Another common use is as a smoke inhalation, with fresh leaves and twigs being burned on a fire and then the smoke inhaled to treat chest complaints, asthma and urinary tract infections. A salve can be used on burns and wounds; and mastication of leaves for scurvy, halitosis and gingivitis (African Infusions, 2019). The plant is used as a tonic and for breast diseases in central Africa and for a variety of ailments in Zimbabwe (Kondlo, 2013; Mandeya, 2018).

Commercial History

Although there has been an informal trade in resurrection bush as a medicinal plant in various southern African countries for many years, the development of formal markets for resurrection products has only been a relatively recent phenomenon, since around 2000. Early players included a Swiss company marketing resurrection twigs as a novelty product to florists, a South African herbal medicine company, a Zimbabwean herbal tea producer and a South African manufacturer of plant extracts for the food and cosmetics industries.

The key moment came in 2001 when a French specialist manufacturer of botanical extracts applied for a patent on a cosmetic formulation based on resurrection bush. Although the patent was later abandoned, it showed the potential for commercial use of resurrection in skin care. Since then, other patents have been taken out by a Korean company, a Chinese company and a French company on anti-ageing formulations using resurrection bush extract, and several high profile cosmetic products have been launched using various resurrection extracts.

Meanwhile the resurrection bush has grown in popularity as a herbal tea ingredient, based as much on its flavour as its medicinal properties, and recent new product launches have included a craft gin and craft beer both based on resurrection bush.

The main drive to commercially develop resurrection in Zimbabwe has been led by Bio-Innovation Zimbabwe, which has played a key role in facilitating the development of Nagoya protocol-compliant Access and Benefit Sharing agreements between international buyers and local suppliers. Although still on a very small scale, Zimbabwe is currently the biggest producer and exporter of resurrection bush in Africa.

One key commercial milestone was the development in 2012 in South Africa of a large-scale resurrection bush cultivation trial by a Swiss company seeking to expand its production. Although the trial was abandoned after three years, it showed the this is an area of key importance to future commercialisation.

Potential Commercial Uses

As a herbal tea, resurrection bush shows very considerable commercial potential. Research by a Zimbabwean team have shown clear similarities between the phenolic content of *M. flabellifolius* and the better-known *A. linearis* (Rooibos) (Bhebhe *et al,* 2015). The product has an excellent flavour, a compelling marketing story, established health credentials and, above all, a series of unique attributes that mark it out as different to other products on the market. It is also caffeine-free. In 2017, Bio-Innovation Zimbabwe launched a project with the support of the Southern African Network for Biosciences (SANBio) to commercialise resurrection tea in 2017 with the aim of selling it in the region and beyond, mostly aiming at high end tourist markets (SANBio, 2017).

The key constraint to development of resurrection tea is the fact that it has yet to be submitted for regulatory approval in terms of key markets (EU Novel Foods, FDA GRAS etc). However, preliminary toxicology trials conducted through the SANBio project have shown that there are not likely to be any technical challenges to regulatory approval, even if the amounts of time and money involved are likely to be substantial. Spin-off products from a successful herbal tea would include the use of resurrection tea as flavourings in other food and beverage products.

The cosmetic market is also showing considerable potential for further development. The ability of resurrection bush to preserve its cells during very dry periods translates well into an extract marketed as a protective agent against aging of the human skin (IRDNC, 2016) (Nott, 2019). Recent advances have focused on novel extraction technologies, with water-based extracts, essential oils and various different solvents, all being trialled for their ability to pull out different combinations of compounds.

The third market opportunity relates to the potential demand for a resurrection bush essential oil. Preliminary research into the oil has shown strong fungicidal and anti-microbial activity (Viljoen *et al.,* 2002), as well as a very pleasing fragrance, showing clear opportunities in the aromatherapy, skincare, and herbal medicine markets.

Market Potential

By far the biggest market opportunity in terms of volume lies in the herbal tea industry. Consumer demand for natural and herbal medicinal formulations is rising, and herbal tea is an excellent and highly accessible format for the consumption and use of traditional and natural remedies. Globally, the US$5 billion/yr herbal tea market continues to show robust growth across all markets (estimated at 6% per annum). Asia-Pacific and Europe are the most prominent markets for herbal teas due to historically high levels of tea consumption in those regions (Allied Market Research, 2020), but the North American market is showing especially fast growth at the moment. As a comparison, the Rooibos tea industry in South Africa employs more than 5,000 people, with production volumes of up to 20,000 MT/yr and an industry value of at least US$100 million/yr. Interestingly, despite being an important export product for South Africa, more than 50% of the Rooibos sales per annum are to local consumers.

Following closely behind the herbal tea market, in terms of its potential to absorb significant volumes of resurrection bush raw material, is the essential oils market. The global essential oils market size was estimated at US$7 Billion in 2019 and is expected to reach US$14.1 Billion by 2026 (Globe Newswire, 2020). The increase in consumer demand for cosmetic products and the benefits of essential oils to the human body are anticipated to create a surging demand from the pharmaceutical industry. According to Ridder (2020) US, UK, China, Canada and Spain are amongst the leading importers of essential oils. Resurrection bush oil can effectively compete with already existing essential oils on the market.

Despite the availability of these market opportunities for *M. flabellifolius,* it is important for current and potential traders of the species to understand regulations involved in order to successfully harness these opportunities. Most companies are not aware of requirements for benefit sharing and therefore compensation for traditional knowledge and adopting Access and Benefit Sharing regulatory requirements to provide a roadmap for future natural resource commercialisation activities (Nott, 2019).

Cultivation/ Domestication Potential

Although there are substantial volumes of currently underutilised *M. flabellifolius* in the wild in Zimbabwe, growth in demand will require domestication and cultivation, as well investment in developing improved and more sustainable harvesting methods. Preliminary trials have shown that *M. flabellifolius* can either be propagated by seed or cuttings. The seeds are quite small and should be sown right on the surface, in a pot with a loose peat moss and perlite mix (acid to alkaline soils) to mimic its natural growing environment. The plants grow primarily from summer-rainfall areas, so spring is probably the best time of year to get them started. Germination is easy and quick in a seed pot kept in a moist, well-lit location. The seedlings should be kept moist, in a sunny spot with good air circulation. Initial growth is slow, but as is the case with many plants, growth accelerates as the seedlings gain in size and in two or three years the bush can become respectably shrubby. Regular applications of dilute, water-soluble fertilizer at half the recommended strength, every 2-3 weeks seem to be beneficial. The plants do well in full sun (Kondlo, 2013).

4.15 Oryza glaberrima

Latin: Oryza glaberrima
Family: Poaceae
English: African rice
Shona: Mupunga
Ndebele: Ingqoloyi
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

Although there are many different wild species of rice in the world, only two are cultivated, being Oryza glaberrima (African rice) and Oryza sativa (Asian rice). The African rice originates from a wild rice species native to Zimbabwe, Oryza barthii., typically found in shallow ponds in mopane woodland in Zimbabwe.

The African rice, Oryza glaberrima, is an annual grass which grows up to 120 cm tall and more in upland or irrigated conditions. The rooting system is fibrous. Dryland types possess simple culms, often rooting at lower nodes and floating types are often branching and rooting at upper nodes. The stems are generally without ramifications (except sometimes in floating culture). Leaves are simple, alternate and attached to the stem by a leaf sheath. The leaf is linear with variable dimensions (length and width) and a short, truncate and membranous ligule (3-4 mm). The inflorescence is a terminal panicle, erect at maturity with ascendant racemose branches. The flower or spikelet is made up of an ovary prolonged by two stigmas and is surrounded by six stamens. The fruit is a laterally compressed grain (grain), often reddish and tightly enveloped.

It is dominantly grown in swampy and wet sites. It is produced in Tropical Africa from Senegal to Central African Republic and DR Congo (Fern, 2014). In Zimbabwe it is found in many parts of the country, especially in lower-lying areas.

Traditional Uses

African rice has been a staple food, highly appreciated for its taste and culinary qualities in various societies (Fern, 2014). In Zimbabwe, it was traditionally grown on circular, raised beds (mateka) surrounding pools of water (Brazier, 2020), and is the main ingredient in a popular dish called Mupunga uneDovi (or Mafake) which blends rice with peanut butter. There are many traditional varieties of African rice in Zimbabwe, including Dembaremba, Munyai, Mutirigu, Kapungare and Mungore, each of which has its own specific characteristics, advantages and disadvantages. Traditional food dishes made from African rice include sweet meats, porridges, puddings, nectars, cakes, bread and pancakes. Other products include rice flakes produced when unmilled rice is soaked in water for three days, then boiled, dried and pounded to remove the husks. These flakes are then popped or eaten as a breakfast cereal. Broken rice grain can be used for confectionary. African rice is also sometimes used as the basis for fermented alcoholic beverages.

Elsewhere in Africa the rice finds widespread use in traditional and ritual ceremonies, e.g. in the Casamance region of southern Senegal, and is also used by descendants of African slave populations in Latin America, including during a ritual called "nyannyan mofu nayan" in Surinam (van Andel 2020).

Commercial History

Domesticated 3,500 years ago in Mali, African rice was cultivated in Africa long before Europeans arrived on the continent. Early Portuguese explorers in the second half of the 15th Century described vast fields planted with rice in the floodplains and marshes of the Upper Guinea coast (de Azurara, 1446). They were impressed by the intensive cultivation systems in practice, and especially the use of carefully contrasted dykes to manage irrigation flows. The Asian rice (*Oryza sativa*) was first introduced to Africa in the early 1500s and rapidly overtook the African rice in popularity within Africa.

Elsewhere, Africa rice was introduced to the New World in the 17th century by means of the slave trade (van Andel, 2010). Unprocessed rice was purchased by slave traders in West Africa to serve as ship provision, and later grown by the enslaved in their home gardens (Carney 2001 and 2005). Until the first Asian rice (*O. sativa*) was introduced in the 1690s, the entire rice cultivation in South Carolina must have been based on *O. glaberrima* (van Andel, 2010). In statistics on rice production in West Africa no distinction is made between African rice and Asian rice (*Oryza sativa*). As a traditional food grain it is not traded internationally, but only within the region of production (Bezançon & Diallo, 2006).

In Zimbabwe it has been traded at a low scale both in formal and informal markets. Research suggests that during the early 19th century, rice was a staple food of the Shona, of great social and cultural value not only as part of their cropping system but also playing a pivotal role in trade between farmers. The crop is grown seasonally in waterlogged fields and has been prominent across much of the north east to the south east of the country where it is still makes an important contribution to household food security and income generation (Naturally Zimbabwean, 2020). In the past barter trading of African rice occurred between farmers, and from the village level right up to Mbare musika.

Potential Commercial Uses

From a cooking point of view, the African rice (*O. glaberrima*) can be utilized in exactly the same way as the more widely consumed Asian rice (*O. Sativa).* It is generally considered to be less suitable for cultivation than Asian rice, having rather more brittle grains that are prone to shattering in the milling process. It is also lower yielding. However, it is easier to grow, and often shows more tolerance to fluctuations in water depth, iron toxicity, infertile soils, sever climatic conditions and human neglect (CGIAR 2021).

In recent years, rice has received increased attention as functional foods due to their phenolic base compounds, high amounts of vitamins, minerals and fibre, which can help to lower cholesterol (Esa et al., 2013). Minerals like calcium, magnesium, phosphorus are also present in African rice together with some traces of iron, copper, zinc and manganese (Oko and Ugwu, 2010). The whole grain can therefore be incorporated in different diets.

Apart from being marketed as a whole grain, African rice can be milled into rice flour. Efforts to augment economic competitiveness in the rice industry include improvements in milling practices, and identification of uses for rice products and by-products (Schramm, 2010). Rice flour can be a base for other products such as cakes, baked breads, puddings and baby weaning foods (Juliano, 2005). A variety of rice-based products exist which are derived from the Asian rice and which can also be explored with African rice. Ready-to-eat convenience foods such as noodles, pasta, crackers, breakfast cereals, puffed rice snacks, noodles have a potential to be commercialised (Esa et al., 2013). Other products that have potential could be paper, fermented beverages, pet foods and bran products (Juliano, 2005).

African rice has one major advantage over the Asian rice, which is that it is resistant to many of the pests that regularly damage Asian rice in situ, including rice yellow mottle virus, African gall midge and nematodes. It also has luxurious wide leaves that shade out weeds, making it much less labour-intensive for the farmers than Asian rice. International researchers have been crossbreeding Asian and African rices to produce superior rice varieties (including the famed NERICA rice – New Rice for Africa), and African rice is considered to be an essential component in current and future rice-breeding initiatives.

Market Potential

Rice is a fundamental food in many cultural cuisines around the world. According to Ricepedia, more than 90% of production and consumption of rice in the world occur in Asia and the share in global rice

consumption was around 87% in 2019 (Priya *et al.,* 2019). The volume of international rice trade has increased almost sixfold, from 7.5 million tonnes annually in the 1960s to an average of 44.2 million tonnes during 2015–2016. Based on the global market scenario, the use of rice as food remains predominant compared to feed and other uses. Rice provides 19% human per capita energy and 13% of human per capita protein (Priya *et al.,* 2019).

In Africa, rice is the staple food of more than half of the population, with more than 50 million metric tonnes produced annually. Yet the continent remains a net importer of ice. According to the International Rice Research Institute, the demand for specialty rice is increasing, with Africa being one of the regions where the demand is increasing at a good rate (Mordor Intelligence, 2020). Domestic rice consumption has been witnessing an upward trend over the past few years in Africa, mainly due to its convenience in preparation and palatable recipes. Sub-Saharan Africa is the world's largest rice importing region, accounting for one-third of global imports. Even though the region's production has increased, it remains heavily dependent on imports. Sub-Saharan Africa consumption has risen nearly 10 percent in the last 5 years, and imports account for more than 40% of its consumption. Within the region, West African countries as well as South Africa, Mozambique, and Kenya are major import destinations. Between 2015 and 2020, Sub-Saharan Africa imports have grown by more than 25% (USDA, 2021), suggesting that the biggest market for *O. glaberrima* would be within Africa.

There is also a growing global market for specialty. In the case of Europe, aromatic and coloured rice varieties are generally not produced in Europe and are imported mainly from developing countries (CBI, 2017). Rice imports from developing countries have increased in recent years since 2012 and the global market of especially red or brown rice is expected to grow owing to the superior nutrient composition of such rice varieties (Grandview Research, 2019).

In 2019, Zimbabwe produced 1,560 tonnes rice, but imported over 150,000 tonnes at a cost of over US$100 million (UN COMSTAT 2020) Although this was almost entirely of Asian rice (for which there is much greater demand), there is nevertheless growing interest from consumers in African rice, which is generally perceived as being healthier and more authentically traditional.

Cultivation/ Domestication Potential

African rice is grown on a wide range of soils. Although preferring fertile alluvial soils, it tolerates low soil fertility. Some cultivars can produce higher yields than Asian rice on alkaline and phosphorus-deficient soils. They are also more tolerant to iron-toxicity. African rice is propagated by seed. Seed dormancy disappears a few months after maturity; for experimental purposes, dormancy can be broken by removing the lemma and palea and about one-third of the albumen, allowing germination in 2–3 days. Before sowing the soil may be prepared but soil preparation is rarely practised. Seed is mostly broadcast without transplanting. The species can tolerate high temperatures and grows well above 30°C, but spikelet fertility is very affected over 35°C reducing yield grains.

Vegetative growth of *O. glaberrima* is very rapid and this development step consists of a juvenile phase of about three weeks followed by an active tillering phase of 3-4 weeks which extends until the flowering and often towards the maturity with the appearance of youthful tillers. Vigorous tillering, high leaf area index and high specific leaf area contribute to its high competitiveness against weeds (Rodenburg *et al.,* 2009). However, culms tend to be weak and brittle, making African rice prone to lodging. The growing season of the crop varies from 3-6 months depending on cultivar (Agnoun *et al.,* 2012). Weeding of African rice in non-flooded areas is manual and often late. In some regions the weed control is combined with land preparation. A first light irrigation favours the germination of weeds, which can subsequently be eradicated. Mechanization and fertilizer application are rarely practised. In floodplain and wet rice cultivation neither crop rotation nor fallow is practised, contrary to the practice for upland rice (Bezançon & Diallo, 2006).

4.16 Parinari curatellifolia

Latin: *Parinari curatellifolia*
Family: Chrysobalanaceae
English: Mobola plum
Shona: Muhacha/ Muchakata
Ndebele: Umkuna
Regions found in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

Parinari curatellifolia is a spreading tree that stands out prominently amongst surrounding vegetation. It has a semi-circular, almost mushroom-shaped, canopy depicting hues of blue-green and grey. It is evergreen, growing to a height of 10 to 13 m (although heights of 23 to 26 m have been recorded in certain areas) (Maharaj & Hugh, 2008). The bark is rough and corky with yellow woolly hairs occasionally present in younger twigs and branches. In common with many other plants in the family Chrysobalanaceae, silica crystals are often found in the wood, giving rise to the tree's nickname of "the hissing tree". Supposedly when cut with an axe, the silica crystals cause the tree to "hiss" loudly.

The simple and alternate leaves are distinctly bicoloured, having a white-silver under-surface and a dark green-grey upper surface. They are inwardly folded with a somewhat oblong shape, having a square base with much tapering at the apex. Petioles are short with an entire leaf margin and velvety hairs covering the surfaces of younger leaves. Mature leaves appear to be darker and more rigid. The sweetly scented inflorescences appear in shades of white, yellow or pink, and are covered in hairs (Orwa *et al.,* 2009). These small bell-shaped flowers are usually visible from July to November. The fruit is a drupe, and is yellow-orange with grey speckles when ripe.

The oval or rounded fruit which has a scaly texture, may take up to a year to ripen and is found at twig ends. These plum-like fruits are ± 50 mm long with a yellow edible flesh. The fruits tend to ripen on the ground in the months of October to January. Within the fruit is the seed which is encapsulated by means of a lid or operculum. The hard and woody endocarp (stone) seed contains 1 or 2 embryos (kernels) (Sanogo *et al.,* 2006). There are 250-350 seeds per kg. It has been recorded that the mobola-plum tree occasionally produces a rather disagreeable smell, the reason for this is uncertain (Maharaj & Hugh, 2008).

The species is widespread in tropical Africa from Senegal to Kenya and southwards to northern South Africa, with the highest concentration in Zimbabwe and the low veld region in South Africa (Kumari, 2017). In Zimbabwe it is widespread and it occurs in four ecological regions.

Traditional Uses

Mobola plum tree is considered a traditional food plant in Africa for both humans and animals, due to its fruits that are a nutritious and important supplement to food supply in the areas they occur. The fruit may be eaten raw or made into a porridge (Orwa *et al.,* 2009). Juice squeezed from mobola fruits is also mixed with maize or finger millet flour to make porridge (Yamamoto, 2007). The juice or syrup is called *'mutotozi'* in some parts of Zimbabwe (Slow Food Foundation). It is said that infants fed with this porridge enjoyed good health. Communities in Mrewa and Mutoko areas of Mashonaland East in Zimbabwe prepare products called *"zvambwa",* using the syrup of *P. curatellifolia* fruit and finger millet (Eleusine coracana) meal. *Zvambwa* are biscuit like products moulded from a gel that forms on heating a mixture of the syrup and finger millet meal. The products have a sweet taste and are consumed by the local residents (Benhura *et al.,* 2015). The crushed pulp is used by some indigenous churches in Zimbabwe for faith healing. As with many fruit trees indigenous to Africa, the fruits are used as an ingredient in fermentable beverages, both alcoholic and non-alcoholic (Yamamoto, 2007; Mariwowo, 2017). The kernels may be eaten raw in the form of nuts and contain a rich oil.

The tree is regarded as sacred, and often plays a role in traditional ancestor consultations through spirit mediums, especially to ask for rains during times of drought (Slow Food Foundation). The tree is also used locally to predict the coming season: it is believed that if the tree produces fewer fruits, there will be a rainier season, and if it produces a larger quantity of fruit, the upcoming season will by drier (Mariwowo, 2017). Game and cattle browse both leaves and fruits; the fruit is used as bait to trap animals such as antelopes. The tree produces abundant nectar and pollen, which makes it popular with honey farmers (Orwa *et al.,* 2009). There are many traditional medicinal uses. An infusion of the roots is used to treat toothache. A hot fomentation of the bark is used in the treatment of pneumonia. A leaf decoction is either drunk or used in a bath as a remedy for fevers. The crushed or pulped leaves are used in a dressing for fractures or dislocations, and for wounds, sores and cuts (Jacke and Green 2006).

Commercial History

Although widely consumed traditionally, first recorded attempts to commercially develop *P. curatellifolia* were undertaken in the early 2000s by PhytoTrade Africa and the World Agroforestry Centre. PhytoTrade's attention was focused on the oil, which was explore for both its potential as a food oil and as a cosmetic oil. Trials were undertaken on different types of oil press to determine optimal pressing technology, and samples were sent to specialist lipid oil manufacturers and cosmetic ingredient suppliers for assessment. Although there was promising feedback, other species also under investigation at the same time showed greater opportunities for quick returns and the research was shelved. The World Agroforestry Centre were meanwhile researching the domestication and improvement of cultivars of *P. curatellifolia* from their regional base in Malawi. They found considerable scope for shortening the period to first fruiting of the trees through selective breeding, but the lack of a formal market for its final products ultimately made the research pointless.

More recently there have been renewed efforts in Zimbabwe by the local research organisation Bio-Innovation Zimbabwe to develop the commercial potential of *P. curatellifolia* as a source of edible nuts. These have proved popular and are now often found in different retail outlets, as well as being available for online sales (Gateway Stream, 2021). There are also occasional fruit jam and jelly products seen in shops and at informal markets.

Potential Commercial Uses

There are three different commercially interesting products from *P. curatellifolia:* the fruit, the nuts and the seed oil. The fruits are tasty and relatively nutritious, high in carbohydrate and vitamin C and containing useful quantities of key minerals (magnesium, phosphorous, iron, manganese and calcium). Traditional products made from the fruit include *"mutotozi"*, a fruit syrup resembling honey in its appearance and consistency (Slow Food Foundation). Being low in sucrose, this has potential as a natural sweetener. It is used to make sugarless cakes, biscuits, *rapoko* snacks, and can be consumed directly, just like honey (Slow Food Foundation). The fruit also makes very palatable jams and jellies, and is a useful base for beverages (Muchuweti *et al.,* 2011). As with many fresh fruits, however, processing and handling is improved if cold storage is available.

The nuts, which resemble almonds in many ways, can be used as a direct (and very flavourful) substitute for other tree nuts, eaten straight as a snack food or as an ingredient in a variety of foods and beverages, including cereals, confectioneries, nut flours, nut milks.

In addition to being edible as nuts, the seeds contain some 40% oil. This oil is pleasant-tasting and can be used as both an edible food oil or as a cosmetic oil for use in skincare formulations.

Market Potential

The global shift in consumers' taste and preference towards organic and natural food products is also being reflected on a small scale at a local and regional level within southern Africa. The two mobola fruit products with clear opportunity on the local and regional market would be the fruit pulp for use as a beverage ingredient and fruit syrup as a natural sweetener. Increasing health concerns are fuelling growth in demand for low-calorie, low-sugar, and high nutritional content fruit products, and both these products perfectly meet this demand. It is reasonable to assume, however, that the fruit flavour is not sufficiently unique and interesting to make it a viable export product (beyond southern Africa).

Where there is clear opportunity for export is in the global market for tree nuts. The rising demand for plant-derived protein, combined with a strong interest in the health benefits of ketogenic diets, has driven rapid growth in demand for tree nuts in recent years. Recorded trade statistics show that around 10 million Metric Tonnes of tree nuts are commercially marketed each year, with the US, China and the EU being the biggest markets (FDA 2020). Market value is increasing at some 8% year-on-year, and is currently valued at around US$60 billion/yr (Research and Markets 2021). This market growth reflects the rising popularity of vegan snacks among millennials, the perceived health benefits associated with tree nuts, and the increase in tree nut-based snack launches. The main tree nuts that have been commoditised globally include almonds, pistacchios, hazelnuts, walnuts, macadamia nuts and Brazil nuts.

The main obstacle to large-scale commercial development of mobola nuts for export is the fact that they are not currently approved for sale in key export markets and would need to go through the appropriate regulatory procedures (e.g. EU Novel Foods, US FDA GRAS, China etc) before they could be sold. However, past experience of doing this with other novel food products (e.g. baobab fruit) has shown that the process of securing regulatory approval can itself act as a valuable marketing and market preparation exercise.

The most immediately accessible export opportunity for *P. curatellifolia* would be in the international market for cold-pressed oils, a $30 billion/yr industry that is primarily driven by the demand for natural skin and hair care products. The cosmetic oil market has much fewer regulatory barriers, as the oil is topically applied rather than internally consumed, and the relentless drive for innovation means there is a continual demand for novel ingredients. *P. curatellifolia* seed oil has an unusual fatty acid composition, being over 90% unsaturated fatty acids, and would therefore have potential industrial applications as well as cosmetic and food use.

Cultivation/ Domestication Potential

Mobola fruit tree propagation and establishment are important for economic development of the species.

Mobola grows best in areas where the mean annual temperature falls within the range 14 - 30°C, but can tolerate 10 - 36°C (Orwa *et al.,* 2009). It prefers a mean annual rainfall in the range 400 - 1,000mm, and thrives in light soils, usually sandy clay loams and friable clays. Seedlings are raised in a nursery and can be transplanted into the field or garden after 2 years. Care needs to be taken when transferring the seedlings because the taproot damages easily. Young plants can be planted in groups of 10 or more, as they occur in nature, and must be watered until they are established; plants grow quite fast; coppice shoots are produced on felled trees. *P. curatellifolia* does not have an invasive root system, and root suckers are produced after root wounding.

4.17 Plectranthus esculentus

Latin: *Plectranthus esculentus*
Family: Lamiaceae
English: Livingstone Potato
Shona: Tsenza
Ndebele: Umbondiwe
Regions found in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical Description

Plectranthus esculentus (often known by its synonym *Coleus esculentus*) is an erect, herbaceous, perennial plant. It is semi-succulent, deciduous, and aromatic, growing to between 0.6 m and 1.2 m tall (Dhliwayo, 2001). Although known for its tuberous roots that are fleshy and swollen, similar to the ordinary Irish potato, it actually comes from the mint family and is not related to a potato in any way. Several hairy stems, woody at the base, unbranched to slightly branched, arise from the tuberous roots. The leaves are deciduous, 50–80 × 13–25 mm, oblong-elliptic, roughly hairy on both surfaces, glandular on the lower surface with toothed margins. Inflorescences are many-flowered, in axillary racemes, 50–80 mm long. Individual flowers are boat-shaped, pedicellate and solitary; the corolla is 14–16 mm long, yellow and expanding to the throat. Flowering time is in winter and spring, after the leaves are shed, and it is the only species within the genus to flower in this season (Busch, 2015). The calyx is 4–5 mm and elongates to 10 mm long after flowering has taken place. The fruits are small, ovoid, brown nutlets that are 1 mm long.

This species thrives in sandy, well-drained soils in rocky savanna, dry woodland and disturbed areas, where annual rainfall ranges between 700–1,000 mm, and where frost is minimal or completely absent. In many countries, including Senegal, Zambia and Zimbabwe, Livingstone potato is found in the wild, and it is only grown where there is a water source.

Traditional Uses

Although *P. esculentus* is today considered a lost crop of Africa, it has a tradition of historical cultivation and use in Africa, particularly East and Southern Africa, going back for thousands of years. It is widely distributed across the continent and is eaten as an edible tuber (Allemann and Hammes, 2003). The tubers are prepared like the common potato and, although they have a bland taste (similar to turnips and parsnips), there are varieties that are more pleasant and have the taste of mint. These tubers may be eaten raw, or the peels scraped off, then boiled, fried and even roasted. They are a delicacy in stews, soups and many other dishes (Bosch, 2015). Other modes of preparation include as a flour, which is sometimes incorporated into a porridge. There are also reports that the leaves are edible and are sometimes consumed as a boiled relish. In parts of Tanzania, rural people collect and pickle the flowers (National Botanical Institute, 1999).

There are several species within the genus *Plectranthus,* many of which have well-documented traditional medicinal uses. The specific properties reported for *P. esculentus* include use as an anthelmintic, to cure stomach ache, nausea, backache, problems associated with the female reproductive system and as a treatment for cancer. It is also believed that the Livingstone Potato increases potency in men. It is likely that there are many more medicinal uses known to traditional healers, but this species has been overlooked by medicinal plant researchers and therefore there is only an incomplete understanding of its full range of traditional uses.

Commercial History

The Livingstone potato has been harvested, cultivated and traded on informal markets in many parts of Africa for a long time. However, it has rarely attracted any large scale commercial investment and has remained a smallholder subsistence crop across its range. In Zimbabwe, it is regarded a minor crop mainly grown for sale and food by women (97%). There are no certified or improved varieties so growers retain seed (91.3%) from the previous crops. Production is mainly done on ridges in wetlands (Kujeke *et al.,* 2015). Cultivation of Livingstone potato is commonly (but not exclusively) practised in the eastern districts of Zimbabwe. In these areas,

the Livingstone Potato is partly grown for household consumption and partly for sale through informal market channels (most commonly on the roadside to passing travellers). The roots are principally sold on the markets of the nearest towns but a considerable fraction of the produce also reaches the markets in the larger cities. Production facts and figures and official statistics on this crop are for the most part not available (Dhliwayo, 2001).

In South Africa, the Livingstone potato was rediscovered by botanists in 2010, having been believed locally extinct with no records of its occurrence for over 30 years. This rediscovery promoted new interest in the plant and keen uptake in cultivation, although this was later reported to be hindered by a shortage of genetic material from which to propagate the plant (Kujeke *et al.,* 2015).

Potential Commercial Uses

Despite being regarded a lost crop, P. esculentus has potential to be commercialised as an alternative to the common Irish potato. In terms of its nutritional profile, Livingstone potato compares favourably to the Irish potato, sweet potato, cassava and taro, all of which are staple tubers in some parts of Africa (Kujeke *et al.,* 2019). According to Allemann and Hammes (2003) chemical analyses of the raw tubers gave crude protein, crude lipid and crude carbohydrate values of 13.5, 0.6 and 81.4 g per 100 g, respectively. The tubers also contain respective levels of 140.3, 50.4 and 0.17 mg per 100 g of Ca, Fe and vitamin A. These are key micro-nutrients often deficient in the Zimbabwean diet. Simply promoting the Livingstone potato as an alternative starch dish (*"Tsenza"*) could therefore create considerable demand. Cooked Tsenza is recommended as a special food for infants, the elderly and the sick people, probably owing to its high digestibility, whilst eating it raw and unpeeled maximises the health benefits from its consumption. The sweet-tasting varieties with low dry matter content could be marketed as a ready-to-eat snack, peeled and eaten raw (Dhliwayo, 2001).

As a further marketing opportunity, researchers have also demonstrated that the Livingstone potato contains some potent polyphenolic compounds that are effective free radical scavengers. Specifically, the research demonstrated clear anti-diabetic activity as a result of this, strongly suggesting that Tsenza could be promoted as a healthier alternative to the Irish potato (Eleazu, 2015).

There are also potential industrial applications for *P. esculentus*. Its flour contains strong antioxidant activity and some bioactive compounds that support its biological properties. The starch quality is similar to that found in cassava and sweet potato, suggesting potential uses as excipients in the food and pharmaceutical industries (as fillers, thickeners, binders, as well as gelling and bulking and water retention agents) (Emmambux and Taylor, 2013). Trials to use it as a pharmaceutical excipient found it worked better than cassava (although not as well as maize starch) (Ochepke *et al.,* 2013).

Market Potential

Zimbabwe produced 309,000 MT tuberous crops in 2019 (FAOStat 2020). This was substantially dominated by Irish potatoes, followed by sweet potatoes. However, it shows a clear opportunity for Livingstone potatoes marketed locally as a healthier alternative. This unique tuber is already known to

local consumers and just needs to be made more widely available. Similarly, value-added potato products have a substantial local market already (especially in the snack and fast food markets), into which *P. esculentus* could tap.

Internationally, the global market for processed potatoes was valued at USD 25 billion/yr in 2019, rising to USD 31 billion/yr by 2022 (Markets and Markets 2020). Of this, only a small fraction is taken by so-called "specialty potatoes" (i.e. any potatoes other than Irish potatoes). However, this has been growing, with a particular focus on so-called "heritage" varieties, representing original potato varieties from Latin America that have largely been lost to the rest of the world. This would suggest potential for the Livingstone potato to be packaged as an African "heritage" species. However, note that *P. esculentus* would need to go through EU and North American regulatory approval processes before it could be marketed internationally.

Cultivation/ Domestication Potential

Tsenza is ususally propagated vegetatively using the edible parts, i.e. the tubers. The tuber pieces (which can be planted as sprouted or unsprouted) are principally obtained from the previous crop and through farmer-to-farmer exchange. The Livingstone Potato is commonly grown on raised beds in wetlands or vleis, although in parts of the eastern highlands cultivation on the flat is practised for dryland production. Field preparation usually commences around the month of June after the completion of all other major field jobs. In wetland production, land preparation starts with clearing of vegetation and then construction of beds, which are preferably laid along the slope to facilitate good drainage. Where level culture is the choice, field preparation involves clearing of vegetation and then burning. In this system of cultivation, deep ploughing is done to encourage development of shapely tubers and to allow easy harvesting.

Generally, planting of seed tubers is done from as early as July up to October. Producers do not apply any fertilizers but the crop still gives satisfactory yields. The use of fertilizers has been notoriously associated with the production of poor-quality unmarketable tubers. The crop is harvested 6-7 months after planting. Bulk harvesting can be done but the crop can also be harvested as needed. The process involves completely pulling up or digging out the plants. The long finger-like tubers which are brittle and turgid are then easily broken off. Most growers have adopted a system of grading whereby the high-quality tubers are selected for the market and the rest is reserved for home consumption and for seed. Pest or disease-infected tubers are unacceptable.

Generally, harvested tubers are kept in cool areas and underground pits. A grass or leaf mulch is normally used for the open storage; ashes and grass are used for the underground storage. In either system of storage, tubers will normally keep for at least 2 months.

Extensive research has been done by UZ scientists on exploiting the tissue culture technique of micropropagation to produce a mass supply of healthy planting material for improved productivity. Results from this study have clearly demonstrated that the addition of NAA: BAP at varying concentrations is essential for optimizing the growth media for micropropagation of Livingstone potato in Zimbabwe. Commercial production of plantlets can, therefore, be carried out to provide healthy planting material for the communal farmers for improved productivity while preserving the germplasm of the underutilised crop at the same time.

4.18 Schinziophyton rautanenii

Latin: *Schinziophyton rautanenii*
Family: Euphorbiaceae
English: Mongongo
Shona: Mungongoma
Ndebele: Umngoma
Regions in Zimbabwe: Zambezi, Kalahari, Central

Botanical Description

Schinziophyton rautanenii (Mongongo) is a small to medium-sized tree, reaching up to 20 m in height with a trunk that can attain a diameter of 100 cm. The bark, which can get to a thickness of 5 cm, is a distinctive light colour – whitish or pale grey – and is smooth at first although later flaking. Free-standing trees have a spreading crown but are more rounded when found in denser stands. The tree is readily identified by its alternate, digitately compound leaves, each with between 5 and 7 leaflets. The inflorescences have a terminal panicle with bristle-like bracts, 3–10 mm long. The flowers are unisexual pale yellow to white; male flowers with pedicel 2–5 mm long, stellate pubescent on both sides; female flowers with pedicel 7–10 mm long, calyx lobes broadly ovate, stellate pubescent on both sides, petals elliptical-oblong. Flowers appear between October and December (Vermaak *et al.,* 2011).

The fruit is an ovoid-ellipsoid drupe up to 7 cm × 5 cm, green, turning grey-yellow when ripe, glabrescent, 1(–2)-seeded. Inside, the seed is encased in a thick, hard and distinctly pitted endocarp. The seed is compressed-ellipsoid, 2–2.5 cm × 1.5–2 cm, containing a white kernel. The endosperm (nut or kernel) is similar in shape and size to a small hazelnut, and creamy yellowish to white in colour (Lee 1979). It contains about 57% lipid and 26% protein. The embryo, embedded in the endosperm, is about 20mm long, with thin, papery cotyledons (Keegan 1982).

The species usually occurs in low to medium altitudes in sandy soil, well developed deciduous woodland on sand, short grassland with scattered trees, wooded hills and amongst sand dunes and sandy alluvium by rivers (Fern, 2014). It can also be found in well-developed deciduous (mopane) woodland on Kalahari sand, often in conjunction with Baikiaea. In Zimbabwe the tree found in 3 ecological regions, mainly in the west of the country.

Traditional Uses

The Mongongo tree is generally found in very dryland areas, and as such its edible fruit and nuts have a long history of human use and consumption. Archaeological evidence suggests that the nuts have been used as a staple food source by the San in the Kalahari Desert in Botswana for at least 7,000 years (Robbins and Campbell 1990). They remain a valuable source of food to several people in the San community in the country today, particularly those who are not involved in farming activities (Hailwa 1998), with nut consumption increasing in times of drought when there are few food options available (Saxon and Chidiamassamba 2005). The fruits and nuts are also widely used in Botswana, Malawi, Mozambique, Namibia, Zambia and Zimbabwe (Van Wyk and Gericke; Misihairabgwi and Cheikhyoussef, 2017) as a strategy by rural people to reduce food insecurity and as an important source of supplementary food particularly during drought.

The fruits, which are similar in flavour to dates, are either consumed fresh or, having dried, are steamed to soften their skins, peeled and then boiled to separate the pulp from the seeds. The tough outer shell of the seeds is cracked by hand, often using stones and axe blades to help split them open, and then the kernels are removed and eaten raw or after roasting. A butter or paste is sometimes made by pounding the nuts. The kernel is also used as a food thickener agent for stews and soups that accompany meat, fish and vegetables (Saxon and Chidiamassamba, 2005).

In Namiba (where the tree is called Manketti), the fruits are famed for producing liquor. The fruits are left in a bucket of water for several days to ferment. The fermented juice is then heated and distilled to produce a distilled alcoholic beverage called Kashipembe (Maroyi, 2018). The edible oil, extracted from the nuts by boiling, is often used in cooking. It is also traditionally used as a body rub to protect and moisturise the skin, especially during the harsh winter months of the dry season in the Kalahari, and as a hair moisturiser (for which purpose it is said to be especially well-suited). The light wood (another colloquial name for the tree is the "False Balsa") is traditionally used to make fishing floats, as well as insulating material and for the construction of coffins and crates. There are also traditional medicinal uses of the rootbark, used to treat stomach ailments.

Commercial History

The history of commercial exploitation of *Schinziophyton rautanenii* goes back to the early 20th Century, when whole nuts were exported from Namibia to Great Britain and Germany. It is not known who the customers were or why this trade petered out after a few years (Graz, 2007), and no statistical data on the production or trade of fruits or nuts were documented.

The primary impetus for more recent commercial development of Mongongo came initially from the Namibian Indigenous Plant Task Team, who identified it in the late 1990s as a species of potential commercial importance to Namibia. This was subsequently taken up by PhytoTrade Africa, who made it one of their priority species in the early 2000s. Initial efforts were focused on the developing the seed oil as a cosmetic ingredient. The INCI name was registered in 2002 and it began being offered to cosmetic manufacturers thereafter. Although initial uptake was slow, it began gaining traction with manufacturers and customers, and by 2010 was well-known to many consumers, especially for its properties as an ingredient in hair care formulations.

One of the main obstacles to commercialisation was the lack of a readily accessible technology for mechanised cracking of the nuts. The first large scale nut-cracking began in western Zambia in around 2012, since when several different technologies have been adapted from other (e.g. macadamia nut) industries and used to crack Mongongo nuts. This has brought the price of the Mongongo oil down with a corresponding increase in demand. More recently, the Zimbabwean organisation Bio-Innovation Zimbabwe has began exploring the use of the nut as a food ingredient. The nuts are especially tasty when roasted and have proved popular with local consumers, the main obstacle to their commercial development being the need to go through appropriate regulatory approval for market entry into key export markets (e.g. EU Novel Foods, FDA GRAS etc). The edible oil has also been used as a food oil, but faces the same key challenge.

Potential Commercial Uses

The two products already under commercial use are the cold-pressed seed oil and the nuts, and both clearly have potential for expansion. Mongongo oil contains unusual fatty acids that make it interesting to the cosmetics industry. Of particular importance are the high levels of eleostearic acid in the oil. Eleastearic acid polymerises under UV light to form a protective film over skin and hair, making the oil an effective barrier and conditioner. It also has significant quantities of natural Vitamin E, protecting it against oxidation and allowing it to be used as a leave-on hair or skin conditioner. The saponification value and refitting agents make it equally as good for soaps (Vermaak et al., 2011). Massage therapists value it as nurturing massage oil, and it protects the skin by acting as a cleanser, moisturiser and emollient (Graz, 2002; Juliani *et al.,* 2007). Mongongo oil-based products that could be (and have been) developed include shampoos, hair conditioners, hair sprays and various skin care products (Transparency Market Research, 2018).

The flavour and nutritional profile of Mongongo nuts make them commercially appealing. The nutritional profile compares very favourably with better-known tree nuts such as the cashew, with relatively high levels of essential minerals such as calcium, magnesium, zinc and copper. From a macronutrient perspective, the nuts are 57% fat and 24% protein, and are noted for their unusually high levels of tocopherol (which makes them exceptionally oxidatively stable and gives them a long shelf-life). Mongongo nuts can therefore be used as an alternative to other tree nuts, marketed as a snack, breakfast cereal ingredient, nut flour, nut milk or in confectioneries.

Market Potential

There is a ready and growing demand locally in Zimbabwe for natural skin and hair-care products. Oil is the base ingredient in most cosmetic products, and is primarily of mineral (i.e. petroleum) origin. As more consumers become aware of this, they are actively seeking natural alternatives, most of which (e.g. palm oil, coconut oil, shea butter) are imported. Mongongo oil therefore has a major opportunity to become one of the key natural ingredients in locally made cosmetic products. The growing interest internationally in Mongongo oil also creates an opportunity, especially if economies of scale can be achieved to bring the cost of production down and allow the oil to enter the market at a much more competitive price-point than is currently the case.

There is also local demand for tree nuts in Zimbabwe, currently met primarily by expensive imported almonds and cashews. Mongongo nuts are an excellent substitute and could easily be promoted as a local alternative. The global demand for tree nuts is growing at a healthy 8% year-on-year, and is currently valued at around US$60 billion/yr (Research and Markets 2021). This is fuelled by the rising demand for plant-derived protein, combined with a strong interest in the health benefits of ketogenic diets. Recorded trade statistics show that around 10 million Metric Tonnes of tree nuts are commercially marketed each year. Mongongo nuts compete very favourably with many of the popular tree nuts, but would require regulatory approval to be successfully launched.

Cultivation/ Domestication Potential

At present Mongongo trees are not cultivated but occur naturally in many parts of western Zimbabwe. The species is adapted to arid tropical and subtropical areas, and grows best in areas where annual daytime temperatures are within the range 18 - 30°C, but can tolerate 10 - 40°C. When dormant, the plant can survive temperatures below -7°C, but young growth can be severely damaged at -1°C. It prefers a mean annual rainfall in the range 500 - 800mm. It requires a well-drained soil, and is not found on compacted clay soils or areas subject to flooding/waterlogging. It grows best in soils with a pH range of 6.5 – 8. Established plants are drought tolerant.

The trees live for at least 100 years, but in nature only start flowering and fruiting when the tree is 20 years old. Domestication and improvement trials will therefore be needed to shorten this time. Fruit production is very closely linked to the amount of rain of the previous season, with crop yields higher in years following heavy rains. High rainfall after flowering has been found to damage the developing fruits, as do fires late in the dry season. Limited data are available on yields, although some estimates indicate yields of 200 - 1000 kilos per hectare in northern Namibia, and about 300 kilos in Angola. A dioecious plant, both male and female forms must be grown if fruit and seed are required (Fern 2014).

4.19 Sclerocarya birrea

Latin: *Sclerocarya birrea*
Family: Anacardiaceae
English: Marula
Shona: Mupfura/ Mutsomo
Ndebele: Umganu
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical description

The marula tree, *Sclerocarya birrea,* is perhaps one of the most notable of all indigenous fruit trees in Africa. A medium-sized deciduous tree, reaching heights of 7 to 17 m, with grey fissured bark, stout branchlets and pale foliage (Mutshinyalo & Tshisevhe, 2003). The rough stem bark is flaky, with a very distinctive mottled appearance due to contrasting light brown and grey patches. The imparipinnate compound leaves are divided into 10 or more pairs of leaflets, each about 60 mm long, dark-green above and lighter below, each culminating in a sharp tip. The flowers are borne in small, oblong clusters, with male and female flowers on separate trees. The flowers are small, with red sepals and yellow petals. The plum-shaped fruits are green when young, maturing to a pale yellow when ripe, approximately 15–25g in weight, about 3-4 cm in diameter, and borne in profusion in late African summer to mid-winter (Feb-June). The outer skin of the fruit has a rather pungent, apple-like odour, and its flavour has been described as similar to the mango (to which it is related). The seed encloses 2–3 soft white edible kernels.

There are 3 documented subspecies of *Sclerocarya birrea,* with the key differences being based around leaf characteristics. Only the subspecies caffra is found in Zimbabwe (Sinthumule and Mzamani 2019). Generally, marula occurs in drier savannah wooded grasslands, riverine woodlands and bushlands, on sandy or sandy loam soils (Fern, 2014). In Zimbabwe, marula occurs in four ecological regions.

Traditional Uses

The marula fruit are so widely known and consumed in southern Africa that in some parts of the region, entire festivals are devoted to celebrating their harvest (e.g. the Oshituti shomagongo festival in northern Namibia and the Buganu festival in Eswatini). They play a key role in both local nutrition and local cultural traditions in certain parts of Zimbabwe, too, with the famed *"Mukumbi"*, an alcoholic beverage made from fermented marula fruit, being seen by many communities as an important component of their cultural identify (Ngorima, 2006). For many marula harvesting communities, the fruit are either consumed fresh or soaked in water to separate out the fleshy pulp from the seeds. The pulp is then boiled to make either a fresh non-alcoholic juice or fermented to make an alcoholic beverage. The remaining seeds are then left to dry and are cracked open (a laborious manual process) to extract the edible kernels, which are then eaten raw or roasted. In some cultures, because of the relatively high labour requirement for cracking the nuts, the kernels are saved for people of higher social status, and are often seen as the "Food of Kings" (Jara *et al.,* 2006). Marula kernels have also been used as a famine food in Zambia and Tanzania. The kernel is ground into butter or a powder which is usually used in vegetable relishes (Wynberg et al., 2003). The kernels mixed with millet meal have also been reported to provide sustenance on long journeys (Jara *et al.,* 2006)

Another important traditional product is the oil from the marula kernels. The tasty and edible oil is traditionally prepared by squeezing it from the kernel in a mortar and pestle or by crushing the marula seeds and kernels in boiling water so that the released oil floats to the top of the water and can be skimmed off (Jara *et al,* 2006). The oil is also used for skin care, rubbed on to the face and body. Very interestingly, another unusual traditional use of the oil is as a meat preservative (suggesting the strong anti-oxidative properties).

Other traditional uses include wood carving, with marula timber being used to make spoons, plates, and decorative animal figures (Shackleton and Shackleton, 2002). Traditional medicinal uses include using a bark decoction to treat dysentery, diarrhoea, rheumatism, haemorrhoids and as a prophylactic against malaria (Mutshinyalo and Tshisevhe 2003). The seeds are also sometimes used as divination tools by some spirit mediums and traditional healers.

Commercial History

The marula tree in Zimbabwe has a history of commercial development and exploitation dating back to the mid 1990s. First steps towards commercial development were led by the NGO SAFIRE (the Southern Alliance For Indigenous Resources) with rural communities in Rushinga and Chiredzi, and were focused on developing the oil as a cosmetic ingredient. Parallel initiatives in Namibia, Botswana and South Africa at the same time eventually led to the establishment of the Southern African Marula Oil Producers Network in 1998, whose early efforts culminated in the launch of marula oil as a Community Trade ingredient by British cosmetic brand "the Body Shop". In 2001, PhytoTrade Africa was launched as the Southern African Natural Products Trade Association, and took on marula as one of its initial focal species. Considerable resources and efforts were devoted to growing market awareness about the health benefits of marula oil. After a while it began to gain traction amongst cosmetics manufacturers and consumers, with several large and high profile brands adopting marula oil as a key ingredient (e.g. Drunk Elephant, Marula.com, Clarins etc.). Today marula oil is a well-established international cosmetic ingredient with strong and growing demand in many markets around the world.

The fruit have also been commercially developed, although the short shelf-life between ripening and fermentation creates significant post-harvest handling challenges. Although distilled marula fruit beverages had been locally produced and marketed in many African countries for a long time, the first mainstream success was the cream liqueur brand Amarula, which uses a marula distillate as its base. Amarula was launched in 1989 in South Africa by the company Distell, and began being exported in the mid 1990s to other countries. By 2010 it had become one of the world's top 10 selling liqueurs, spawning a number of other copycat brands (some of which genuinely use marula fruit and others of which simply use artificial flavours). Other fruit products marketed within Africa include jams and jellies, fruit leathers and dried fruit powders. Unfortunately marula fruit is not approved for sale in Europe or North America and would require regulatory compliance measures for successful export. Recently a newly-formed marula sector support initiative, supported by the Swiss and German governments, has begun exploring modalities for this.

Another marula product that has experienced recent growth has been the kernels, sold as edible tree nuts. Although not so well-suited for eating as a snack (being rather soft), they go well as ingredients in a range of products including confectionary, baking, nut butters and as a substitute for pine nuts. As with the fruit, however, these nuts cannot legally be sold in many export markets. In Zimbabwe, the organisation Bio-Innovation Zimbabwe has been leading efforts to promote the production and sale of marula nuts as a health food ingredient.

Potential Commercial Uses

Undoubtedly the quickest route to expanded commercial use of marula would be through upscaling current demand for marula oil in the cosmetic market (especially through targeted marketing in non-traditional markets such as Africa, Latin America and Asia). Additionally there are two potential new products that could be developed to further grow the demand. Importantly, these products both complement each other in that the one is essentially a by-product of the other.

The first would be the fruit pulp as be a base for the development of beverages, both alcoholic and non-alcoholic. This would need to be stable, aseptically packed and flavourful. Various attempts have been

made historically to achieve this (including a Ceres marula fruit juice in the early 2000s), but none have successfully managed to combine all of these. It could be in the form of a frozen pulp (as is often used in the case of e.g. granadilla), a concentrate, a syrup or a purée. EU Novel Foods approval would also need to be sought and granted, on the basis that marula is a traditional food in many African countries with a long history of safe use.

The second would be to adapt the oil, currently marketed as a cosmetics oil, and begin selling it as an edible oil, competing with high-end oils such as olive oil, argan oil, walnut oil and avocado oil. This would also require EU Novel Foods approval (and other regulatory approvals), but would unlock some significant new market opportunities. Marula oil has a similar fatty acid profile to olive oil (high in oleic acid), but some of the phytosterols present in the oil make it much more oxidatively stable than olive oil. This means the undesirable aldehydes that are formed when heating olive oil (and many other edible oils) are much less likely to be found in marula oil, making it a safer and healthier option than almost any other food oil currently on the market.

Further growth in demand for marula products could also be achieved through expanded marketing of the kernels as edible nuts. Marula kernels can be utilized in various products such as snacks, breakfast cereals/ muesli and confectionary. Products like nut flour and nut milk have had a growing interest among consumers, there is potential for marula nut flour and milk to compete with other tree nut products already available.

Market Potential

Marula oil is already well-established in the global market for cosmetic oils, which is currently valued at over US$50 billion/yr (Grandsview Research, 2019). Whilst Europe will retain the prominent value share in the global marula oil market (mainly because it is home to many of the major cosmetic manufacturers), other markets are likely to see significant growth. Included in this are the domestic and regional markets, with many local consumers in Zimbabwe coming to recognise the damage caused by using petroleum-based skincare products and actively seeking natural alternatives.

The global fruit beverages market is a USD 35 billion/yr industry (Grandsview Research, 2019). Although heavily dominated by orange juice, a rising demand for novel and chemical-free products has seen several new, often organically-certified, fruits coming on to the market. Marula's refreshing flavour profile, unique back story (especially the association with elephants) and inherently organic, chemical-free production, make it a strong candidate for global launch as soon as the technical and regulatory challenges have been addressed.

The market for healthy edible food oils is another substantial opportunity. The backlash against mass-produced, solvent-extracted cooking oils high in saturated fats has driven demand for cold-pressed natural oils. The exceptionally high levels of oxidative stability in marula oil make it particularly desirable in this regard. Of the current global demand for cold-pressed food oils (around US$25 billion/yr), more than half (US$15 billion/yr) is supplied by olive oil. This creates a substantial opportunity for marula oil, which competes very favourably with olive oil on many levels.

Cultivation/ Domestication Potential

Commercialisation of the Marula sector will require domestication and cultivation to improve genetic strains, quality and reliability, as well as sustainable harvesting from the wild resource. The marula tree is highly sensitive to frost and grows best in frost-free areas under warm conditions. It is adapted to dry and hot weather conditions. It thrives in arid and semi-arid areas with summer rainfall varying from 250 to 1 000 mm. It is also adapted to poor soils mainly sandy soil or, occasionally, on sandy loam of pH in the range 4.5 - 6.5 (Fern, 2014). Application of fertiliser depends on the age of the tree and its bearing status. Nursery medium recommendations are a 3:1:1 or 1:1:1 mixture of course sand and manure and well-drained, sandy loam (DAFF, 2010). Irrigation also depends on the season and soil type. Matured trees need periodical watering, especially if they are growing in a sandy soil or if there has been no rain. There is insufficient literature regarding the diseases of marula or even fungi that occur on this tree however the known pests affecting the plant are the marula fruit-fly, the red marula caterpillar and the marula beetle (DAFF, 2010).

4.20 Trichilia emetica

Latin: *Trichilia emetica*
Family: Meliaceae
English: Natal Mahogany, Mafura
Shona: Muchichiri/ Mutsikiri
Ndebele:
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical description

Trichilia emetica is a spectacular evergreen tree which grows up 30 m in height. Its trunk is swollen at the base, becoming fluted with age. The reddish grey-brown bark has fine, shallow striations and scales. The branches have an erect or partly spreading appearance, creating a triangular-shaped crown when young, becoming more rounded and dense when mature. The tree has a shallow and non-aggressive root system. The leaves are up to 50 cm long, unevenly compound with 3-5 pairs of leaflets plus a terminal one, dark green and glossy above and covered with short brownish hairs below. The creamy to pale yellow-green flowers are produced on short, congested axillary panicles, fragrant, with 5 thick petals, about 2 cm, surrounding a hairy centre of stamens. The fruit is rounded, furry, red-brown capsules up to 3 cm across, split into 3 or 4 parts to reveal 3-6 shiny black seeds 14-18 mm in length, each with a fleshy scarlet or orange-red aril almost covering the seed. A clear neck to 1 cm long connects the capsule to the fruit stalk (Orwa *et al.,* 2009).

Trichilia emetica grows in riverine forest and in various types of woodland. It is also ocassionally found on more fertile soils of river banks, floodplains and escarpment miombo (Mashungwa and Mmolotsi, 2007). It is regarded as an indicator of areas with palatable grass species. It grows naturally through sub-Saharan Africa from Senegal to the Red Sea, throughout East and Central Africa to Congo and South Africa. In Zimbabwe, it is found in four ecological regions.

Traditional Uses

The Natal Mahogany has many different traditional uses. The unusual, oily arils coating the seeds secrete a sweet, milky, potable liquid. This liquid, called *mafurra,* is especially popular in Mozambique. The skinned seeds are also edible and are eaten raw or soaked in water and ground, the resultant liquid is usually mixed with spinach (Orwa *et al.,* 2009). Domestic animals feed on its leaves and the tree is occasionally used for bee forage. The wood is used as timber as it is soft yet firm and works well. Being relatively fast-growing, the tree is often planted as an ornamental or shade tree.

The seed contains high oil concentrations, known commercially as "Mafura". The seed of *Trichilia emetica* yields two kinds of oil, Mafura oil which is extracted from the fleshy seed envelope (sarcotesta) and Mafura butter extracted from the kernel. In traditional extraction they may be produced separately, whilst in commercial extraction they are combined into a single product. Mafura oil is edible, but Mafura butter is unsuitable for consumption because of its bitter taste. It is used in soap and candle making, as a body ointment, wood-oil and for medicinal purposes (Mashungwa and Mmolotsi, 2007).

In traditional medicine, the seed oil has been used to treat various ailments such as abdominal pains, dermatitis, haemorrhoids, jaundice and chest pain. This species is also known for its emetic (hence the name *T. emetica*), diuretic and purgative properties and for induction of labour (Komane *et al.,* 2011). The oil is consumed to relieve rheumatism and to treat leprosy and fracture (Mashungwa and Mmolotsi, 2007). The bark is used in the treatment of skin complaints. Pieces of bark or powdered bark are soaked in warm water and used as an emetic or enema. It is valued for providing shade and protection for livestock (Orwa *et al.,* 2009).

A decoction of the bark and roots is a remedy for colds, pneumonia and for a variety of intestinal disorders including hepatitis. In Senegal a macerate of root bark is used to treat epilepsy and leprosy, while in Mali powdered root is given to treat cirrhosis, river blindness, ascariasis and dysmenorrhoea. A decoction of the roots is also used to treat infertility and to induce labour in women (Mashungwa and Mmolotsi, 2007). In Zimbabwe the bark is used as fish poison.

Commercial History

Historically the main product from T. emetica has been the Mafura oil, artisanally produced and marketed as a food oil in Mozambique. Whilst the majority is produced for own consumption, smaller surplus volumes are retailed to others. A by-product called "Xibehe", an edible pulp, is also consumed at home or marketed on to others. One study in Zavala District in Mozambique found that harvesters were producing an average annual production of 6.9 Litres Mafura oil per year and 23.3 kgs of the edible pulp (Matakala *et al.,* 20007).

Mafura butter, a different product to the oil, has long been exported from East and Southern Africa. It is reported that in the 1960s and early 1970s, up to 20,000 MT/yr of Mafura butter were exported from Mozambique to Portugal for use in soap-making. This industry disappeared at Mozambican independence in 1974 but, 30 years later, began to reappear in Mozambique. The main driver of growth in production of Mafura butter was the trade association PhytoTrade Africa which, in 2001, selected Mafura butter as on of its priority value chains for long term investment. Samples were produced and sent to cosmetics manufacturers around the world and, by 2010, Mafura butter had become an established African ingredient for cosmetic manufacturers. Production spread into other southern African countries, and today it is actively produced and marketed in Zimbabwe, Zambia, Malawi, South Africa, Eswatini and Mozambique. The main exporter is Mozambique from which an estimated are 100–300 t/year are produced and exported (Mashungwa and Mmolotsi, 2007).

Potential Commercial Uses

T. emetica has a range of potential applications and products for commercial development. The trees fruit abundantly (between 65 and 80kg fruit per tree/yr) and the oil content of the seeds exceeds 50%. The fatty acid profile of the oil is broadly similar to palm oil (40% palmitic acid, 31% linoleic acid and 26% oleic acid). Although Mafura oil and butter are already marketed to the cosmetics industry, several other potential industrial applications exist. Soap-making is an obvious one, and this has been a long-time use of Mafura in Mozambique. *T. emetica* seeds yield high oil quantity with low qualities due to higher levels of acidity (Nchimbi, 2020). The saponification value guarantees the possibility of using *T. emetica* seed oil in soap making (Adinew, 2014) . However, the oil requires purification in order to bring levels of acidity to acceptable standards and guarantee its normal use in soap making.

Mafura butter is also used to treat a wide range of skin ailments, such as athlete's foot, cold sores, wounds and cracks, arthritis therefore it can be utilised as a pharmaceutical ingredient. The butter has a high melting point and low spreadability, which limits its emollient properties. Interesterification of Mafura butter has been found to produce formulations with improved physicochemical and cosmeceutical properties (Poojary and Passamonti, 2020). *Trichilia oil* also produces a good finish on wooden surfaces and would compete successfully with other commercial wood oils (Grundy and Campbell, 1993), and has also been successfully trialled as an ingredient in shoe polish and floor polish.

Recent investigations into the potential for Mafura oil/butter to be used as a bio-diesel have had promising results. The yields are relatively high and the oil meets the quality requirements of international regulators in the US, EU and Brazil (Joao et al 2020). The acidity does need to be reduced though esterification, but the result compares favourably in quality to jatropha and soybean oils.

There is another completely different potential commercial use of the Natal Mahogany. *T. emetica,* in common with other plants in the Meliaceae family, contains a class of compounds called liminoids that have strong insecticidal activity, acting to disrupt insect growth, inhibit reproduction and serve as an antifeedant. These occur naturally in the plant as a defence against herbivory, but can be used commercially. The liminoids are found in the bark. Their one major advantage over other comparable nat-

ural insecticides (e.g. Neem) are that they do not degrade under UV light (i.e. sunlight) and have a lengthy shelf-life.

Market Potential

Mafura oil/butter are already well-established in the global market for cosmetic oils, which is currently valued at over US$50 billion/yr (Grandsview Research, 2019). There has been a pull towards bioactive ingredients in this sector, and Africa's novel natural ingredients such as Mafura oil have gained considerable attention owing to this trend (Persistence Market Research, 2018). Whilst Europe will retain the prominent value share in the global Mafura market (mainly because it is home to many of the major cosmetic manufacturers), other markets are likely to see significant growth. Included in this are the domestic and regional markets, with many local consumers in Zimbabwe coming to recognise the damage caused by using petroleum-based skin and haircare products and actively seeking natural alternatives.

The global soap market is substantial, at over USD 34 billion/yr in 2019, rising to USD 55 billion/yr by 2027 (Fortune Business Insights 2020). The global COVID-19 pandemic has accelerated growth in this market. Although the key trend is towards liquid soap (for which Mafura is not suitable), the bulk of demand (especially in Africa) is for solid bar soaps (for which Mafura is ideal).

Mafura butter competes in the cosmetics industry directly with Shea butter from West Africa, for which annual trade volumes exceed USD 1 billion/yr (GrandView Research 2019). Africa currently exports over 250,000 MT Shea butter products to Europe alone every year (CBI 2021), giving an indication of the potential scale of this sector.

The biodiesel market is essentially unlimited, but the determinant of success would be price. As T. emetica trees typically take 10 to 15 years to begin yielding fruit, it seems hard to envisage that they could be a competitive source of biodiesel.

The market for insecticides, while heavily dominated by organophosphates, is showing significant appetite for botanically-derived products. Currently the total market value is USD 15 billion/yr (Mordor Intelligence 2021), of which bio-insecticides represent only a small, but by far the most dynamic, fraction at present. Asia-Pacific is both the biggest and fastest-growing market for insecticides, and interestingly much of the research on the insecticidal properties of Mafura have been undertaken by Asian researchers.

Cultivation/ Domestication Potential

T. emetica is one of the fastest-growing indigenous tree species in Zimbabwe, thriving in areas with moderate to high mean temperatures (19–31°C). It is found from sea-level to 1800 m, but does not tolerate frost. It requires an annual rainfall of at least 500–1000 mm, the lower ranges only where groundwater is available. It is capable of withstanding long periods of drought. They should be well drained and have an elevated ground water table.

Trichilia emetica regenerates naturally from seed or from suckers after wounding. Seeds are perishable and should not be allowed to dry and should be sown as soon as possible. To extract the seed, ripe fruits are spread on a mesh in the shade until all fruits have opened. Seeds are then separated and the fleshy envelope is removed by maceration in water, which greatly increases the germination rate. Subsequently the seed is spread out to allow the surface to dry. Well-prepared seed germinates within 10–20 days after sowing. One kg of fruit contains about 250 g of seed; the weight of 1000 seeds is 1–2 kg. Seedlings can be planted out when 6–8 months old and initially require shade. They are best planted out under a stand of about 30 existing trees per ha to provide shade. Recommended spacing in pure stands is 3 m × 3 m for fruit production. Propagation is possible from cuttings. Cuttings can be taken from layered branches, roots or 1-year-old coppice shoots. They can be planted in the sun, but preferably under some shade.

In plantations weed growth should be controlled since seedlings are sensitive to competition. Removal of weeds before planting is needed and several weedings should be carried out in the first few years. In terms of pests and diseases, many mammals feed on the leaves as do the larvae of the white-barred charaxes butterfly (*Charaxes sp.*). Brown leaf scales have also been observed on leaves, resulting in circular holes of up 7 mm in diameter when the scales drop off (Mashungwa and Mmolotsi, 2007). Under optimal conditions trees start producing fruit when 6 - 8 years old, seed yields of individual trees vary greatly per tree and per year and range from 20 - 180 kg/year, averaging 45 - 65 kg. A dioecious species, both male and female forms need to be grown if fruit and seed are required (Fern, 2014).

4.21 Uapaca kirkiana

Latin: *Uapaca kirkiana*
Family: Phyllanthaceae
English: Wild loquat, mahobohobo, sugar plum
Shona: Muzhanje
Ndebele: Umhobohobo
Regions in Zimbabwe: Zambezi, Central, Save-Limpopo

Botanical description

Uapaca kirkiana, commonly known as 'Wild loquat', is one of the 60 species of its genus. It is native to the Miombo woodlands of Southern Africa and is mainly distributed in semi-dry and dry areas, although it tolerates wetter conditions. *U. kirkiana* is a small to medium-sized evergreen or semi-deciduous tree with multiple and spreading branches which form a dense, rounded crown. The tree can reach a height of 5 - 12 m and a diameter of 5 - 25 cm, giving the trunk a short and stout appearance. The dark grey or grey-brown bark is thick and deeply cracked. The leaves, which are distinctive and large (around 170 X 110 mm), are simple and alternately arranged in clusters, mostly concentrated at the ends of each branch. Young leaves are covered with coiled hairs on the under-surface.

Flowers are pale yellow, borne on short, slender axillary peduncles and are not particularly distinctive. The species is dioecious and therefore outcrossing. The unisexual inflorescence originates from axillary positions among or below the leaves, on the previous season's wood of the branchlets in both male and female trees. Male flowers occur in dense masses, whereas female flowers are solitary. The fruit is round, thick-skinned, yellow-brown and up to 3.3 cm in diameter. The flesh is yellowish, edible and sweet tasting with a pear-like flavour, although the skin is notably astringent. Each fruit contains 3-4 white seeds, each one up to 2 cm long and 1.3 cm. thick. Fruits ripen towards the end of the dry season (July to October).

U. kirkiana is one of the most dominant and abundant wild fruit trees found in Zimbabwe, often forming dense stands in areas of *Brachystegia* woodland. It is widely distributed across many parts of Zimbabwe.

Traditional Uses

U. kirkiana is one of Zimbabwe's most popular indigenous fruit trees (Dhliwayo-Chiunzi *et al.,* 2014). Fruits are collected from the wild and from trees deliberately retained in the fields when forests are cleared for cultivation of other crops. Fresh, unprocessed fruits are consumed at household level and are also sold on the roadside as well as in informal fruit & vegetable markets. The fruits can be processed into both alcoholic and non-alcoholic beverages, often being fermented into a wine. They are also made into traditional cakes and mixed into sorghum or millet porridge.

During the short but intense fruiting season, the fleshy fruits are also an important source of additional animal feed. The leaves are used as fodder for cattle throughout the year, but especially at the end of the dry season when there are a few alternatives (Ngulube, 1996). The flowers are attractive to bees and the trees ae much valued by beekeepers.
A widely-reported medicinal use is in the treatment of indigestion. The roots are soaked in water for around 15 minutes and then the liquid is drunk to relieve the pains of indigestion, especially associated with gluttony and over-consumption.

The reddy-brown wood, being durable and relatively termite-proof, is used to make furniture and is also an effective charcoal and firewood (Orwa *et al.,* 2009). The leaves are traditionally used as a cockroach repellent in households, although there is no documented information on the criteria and effectiveness of use. In other countries such as Malawi and Zambia, a blue dye is made from the roots of U. kirkiana and a salt for seasoning food is also obtained from the wood ash. The thick-broad leaves are used as wrapping for processed food.

Commercial History

Over the years, *U. kirkiana* has been mostly traded in informal markets in the form of fresh, unprocessed fruit. Fruit collectors harvest the fruit and either sell them along the roadside to passing travellers or bring them to peri-urban markets for onward sale. Traders also buy them from rural harvesters, transport them to urban areas and then either retail them from the back of a vehicle or wholesale them on to other vendors. The fruits tend to fetch a low price on the market as they are highly perishable and flood the market during the production season.

The informal sector has also seen plenty of informal value-addition, with different mazhanje products such as juices, squashes, wines, beer and cakes having appeared on the market at various times (Ngulube *et al.,* 1995). In Zambia, the fruit is used in the

commercial production of a wine called Masuku, a local brew sold in supermarkets (Muchuweti et al., 2006). In Malawi the fruit is also used to produce an opaque beer called 'napolo ukana' and there are different brands producing a wine from the fruits (Orwa et al., 2009).

The NGO SAFIRE undertook trials in Zimbabwe in the late 1990s to produce both a jam and a fruit roll from the processed pulp. Although moderately successful, neither product was ever manufactured commercially and there is no evidence of any large scale processing of the fruit in Zimbabwe.

Potential Commercial Uses

The macronutrient composition of *U. kirkiana* fruit compares well with other wild fruits from sub-Saharan Africa (Chawafambira *et al.,* 2020), with notable levels of iron, magnesium and zinc, suggesting that there are opportunities process the fruit into nutrient-dense food and beverage products. The flavour profile is also appealing. The fresh fruit is highly perishable and the emphasis should therefore be on developing value-added products with a longer shelf life. Commercial successes in Malawi and Zambia indicate that the quickest returns would be from the development of alcoholic and non-alcoholic beverages. The current trend towards new and exotic alcoholic liqueurs create a clear opportunity for novel mazhanje products, and the fact that it is well-known to local consumers enhances the likelhihood of a positive consumer response.

U. kirkiana lends itself well to jams, and there is considerable scope to develop new and varied jams and preserves, as well as fruit leathers and related products. One innovative product that has been developed by researchers is a probiotic mazhanje jam, inoculated with the beneficial Lactobacillus rhamnosus bacterial culture. This has multiple benefits, including allowing the jam to be described as "probiotic" improving many of its sensory characteristics and enhancing the bioavailability of two critical micronutrients, zinc and iron.

Pharmaceutically, *U. kirkiana* stem bark is likely to be a natural source of Betulinic acid, a potent phytochemical with marked anti-tumour activity that is being actively explored for cancer prevention and treatment. Betulinic acid is also a known anti-parasitic agent, and has been used to treat malaria.

As with any fruit, U. kirkiana contains an array of different polyphenols and tannins. Researchers have shown significant anti-oxidant activity associated with the fruit and particularly the tannin-rich (and notably astringent) skins. These tannins appear to be effective in preventing oxidation of low-density lipoprotein (LDL), which may be helpful in preventing coronary heart disease. This suggests strong health benefits to be derived from potential commercial fruit products from the wild loquat.

Market Potential

The first and most obvious opportunity relating to *U. kirkiana* comes from improved supply chain logistics around the fresh fruit. Although perishable, refrigeration will prolong shelf-life, extending the

marketing season and ironing out the price fluctuations that occur when there is a temporary glut of product. The current trend in Zimbabwean restaurants and hotels of offering wild fruits as starters is a clear opportunity, building on a growing consumer awareness and appreciation of traditional foods. There is also a refreshing (and long overdue) shift amongst consumers towards supporting local production. Mazhanje epitomise local fruits to many Zimbabwean consumers, and have a strong inherent brand as a result.

Although dominated by a homogeneous mixed fruit jam, there is a differentiated market in Zimbabwe for other jams and preserves. With investments in quality and packaging, it is expected that there would be modest demand for an array of *U. kirkiana* products such as jams, dried fruit rolls and fruit nectar.

A more substantial way of getting the wild loquat on to the market would be through the production of a flavourful, aseptic purée or syrup that could be used as a food or beverage ingredient by commercial manufacturers. Zimbabwean consumers have a strong preference for sweet cordials and syrups, with many supermarkets devoting an entire aisle to cordials. A mazhanje cordial with an authentic flavour would likely do very well in this market, assuming it could be produced at a competitive price point.

Finally, the demand for novel alcoholic beverages continues to grow, and Zimbabwe has a clear vacancy for a uniquely Zimbabwean beverage (to be to Zimbabwe what marula cream liqueur is to South Africa). U. kirkiana would lend itself to a variety of products including a fruit wine, a liqueur, a craft gin or a schnapps.

Cultivation/ Domestication Potential

Considerable work has been done on the domestication and cultivation of *U. kirkiana,* and the tree grows well in a mixed agroforestry system. Seed selection is the first priority. For good quality seed, fruit should be harvested directly from the tree done. Seeds are manually extracted from the fruit by removal of the fruit skin and seed separation from the mesocarp. The seed is short-lived and, to prolong viability, temporary cold storage is useful, although it should not exceed four weeks for best germination results.

In natural stands, *U. kirkiana* forms an association with mycorrhizae which is an essential feature of forest and woodland ecology. Direct sowing into polythene tubes is advisable rather than direct field seeding, which results in low germination success and subsequent survival (Mwamba *et al.* 1992). Germination usually takes 2-6 weeks and the species can tolerate poor, shallow, gravel and sandy loam soils with a pH ranging from 4 to 6 (Fern, 2019). In natural populations, *U. kirkiana* seedlings grow in partial shade of the mature trees. Seedlings should therefore be raised under partial shade for the first few months to avoid high temperatures and direct insolation. Afterwards, however, they require full exposure to the sun.

Vegetative propagation using stem cuttings has been tried, but with little success. *Uapaca kirkiana* is a slow growing tree under poor or no management conditions, but growth rate improves tremendously following suitable inoculation and clean weeding. In planted stands, fruiting occurs within 9-10 years. Although precise fruit yield figures are not available, fruit loads exceeding 600 fruits per tree (about 18g per fruit) have been recorded before.

4.22 *Vigna subterranea*

Latin: Vigna subterranea
Family: Fabaceae
English: Bambara nut
Shona: Nyimo
Ndebele: Imdlubu
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical description

Vigna subterranea, the Nyimo bean, is an annual leguminous creeper, widespread across Africa but believed to be of West African origin. Its taproot, which is well-developed and extends deep underground, has profuse geotropic short lateral roots up to 20 cm long. The roots possess nodules for nitrogen fixation, in association with African wild-type Rhizobia (Heuzé V *et al.,* 2016). The trifoliate leaves, around 5 cm long, are attached to the stem by the petiole. The petioles are about 15 cm long, stiff and grooved, and the base is green or purple in colour. Leaves and flower buds arise alternately at each node.

The small yellow flowers are typically papilionaceous, borne in a raceme on long, hairy peduncles which arise from the nodes on the stem. The sepal enlarges and, after pollination and fertilisation, the fruit/pod develops above or just below the soil surface. The pods range in colour from yellowish green through to a reddish/purple hue when ripe. The single-seeded pods are small and round, approximately 2.5 cm in diameter, and with a wrinkled appearance. The hard, smooth seeds are usually round and vary in size (8.5 – 15 mm in diameter) and colour (ranging from white, cream, dark brown, to red or even black). They may also be speckled or patterned with a combination of the colours. The average seed mass is about 500 to 750 grams (DAFF, 2016).

The species is adapted to hot, dry and marginal soils. In Southern Africa, Zimbabwe is the centre of its production. It can also be found in tropical parts of America, Asia and Australia but the present extent of cultivation outside Africa is almost negligible (Heuzé V *et al.,* 2016).

Traditional Uses

V. subterranea has been cultivated as a food crop in Africa from at least the 14th century AD. It has long been an important source of affordable protein in the diets of Africans, especially in regions where animal protein is comparatively expensive (Mubaiwa *et al.,* 2018), and only began losing its importance with the arrival of the groundnut (Arachis hypogaea) (Fern, 2014). Even so, it remains the third most commonly eaten legume in Africa after groundnut and cowpea (Heuzé V *et al.,* 2016).

In many African countries the Bambara nut is considered a 'women's crop' because it is mostly produced, sold, cooked and served by women (Azam-Ali *et al.,* 2001). Perhaps the most widespread use of the Bambara nut is as a snack, with the beans being removed directly from the boiled pods, often with added salt. In Zimbabwe the boiled bean is also combined with maize, peanuts and cowpeas to make the popular 'mutakura' dish, also known as 'umpakulwa' in Ndebele. In East Africa, the beans are roasted, ground and used as a base for soups which can be either bland or made zesty with added chillies (National Research Council, 2006). In Nigeria, a common breakfast food is a cakey pudding made from the dried Bambara nut, which is ground into a fine powder, mixed with palm oil, water and pumpkin leaves and then poured into banana leaf wraps before being boiled (Döring , 2021). It can also be ground into a meal which is used to prepare porridge and other dishes. Young pods are eaten in stews and the roasted seed can be used as a coffee substitute.

Some traditional medicinal uses can be found in literature. In Botswana, for example, the black seeded landraces have the reputation of being a treatment for impotence (National Research Council, 2006). Leaf preparations are applied as a poultice to abscesses and infected wounds. The leaf sap is applied to the eyes to treat epilepsy. The roots are sometimes taken as an aphrodisiac. Pounded seeds, mixed with water, are used to treat cataracts (Kern, 2014).

Commercial History

In Zimbabwe, the Bambara nut has been grown by small-scale farmers, mostly as a subsistence crop. As elsewhere in Africa, the Bambara nut is viewed as being predominantly grown by women and is often given a lower priority within the village in terms of land allocation for cultivation (Hillocks *et al.,* 2012). The surplus after home consumption (both fresh and dried) is sold to individuals engaged in street sales at local markets such as Ngundu market or Mbare Musika (Makanda *et al.,* 2008). The raw seed has been sold in supermarkets as well.

In the 1990s, a Zimbabwean company, Tulimara, introduced canned Bambara nuts on to the local market. It reportedly sold as well as any other canned bean, with quantities reaching nearly 50,000 cans a year (National Research Council, 2006). More recently other companies have also followed suit within Zimbabwe. Canning has also taken place in other African countries, the best-known example of which was a Ghanaian company product of canned Bambara nuts in gravy, which was alleged to have sold well for several years. In Zimbabwe, cross-border traders have also purchased Bambara nuts for packaging and distribution in South Africa (Hillocks *et al.,* 2012).

Although Bambara nuts have a long history of use and cultivation, they have never been the subject of sustained investment by researchers and funding bodies, and have not moved into large-scale commercial growing. Cultivation is still from the local landraces rather than improved varieties, and the mechanized equipment for post-harvest dehulling and processing have not yet been developed. Constraints to commercial use have been attributed to the hard-to-cook (HTC) and hard-to-mill (HTM) phenomena (National Research Council, 2006). However, because it takes place in the informal sector, much of the trade in Bambara nuts is invisible, and it is likely that global volumes of production of this species are far bigger than is evident from literature.

Potential Commercial Uses

The Bambara nut is relatively easily-grown, highly nutritious and culturally familiar to many Zimbabweans. Nutritional properties per 100 g include high levels of protein (18.8 g), carbohydrate (61.3 g), calcium (62 mg), phosphorus (276 mg), iron (12.2 mg), beta-carotene, Vitamin B and a range of essential amino acids (including particularly high levels of methionine). It also contains traces of vitamin C and some cultivars are known to contain vitamin A (Nwinyi, 2019). The dried leaves can be used as a fodder, and the seed shells are a useful fuel.

The two main applications of commercial potential are as a fresh or preserved bean or as a dried, milled bean flour.

On the whole bean side, the main commercial potential lies in the large-scale use as a fresh or dried bean. The main obstacle to this is the lengthy cooking time required, which is a deterrent to many in today's era of fast food and instant gratification. This is overcome through canning pre-cooked Bambara nuts. This has the added advantage of allowing for different flavours and blends to be included in the final canned product. The versatile and tasty beans can be used in a variety of dishes, and are an excellent source of plant-based protein for the growing numbers of vegetarians around the world. Bambara nuts also have potential as a novelty snack, as a direct replacement for the many peanut-based snacks.

The dried Bambara nut bean flour has been the subject of some recent research efforts (Nwadi *et al.,* 2020). Already commonly used to thicken and flavour cereal products, it has potential applications in the production of pasta, instant porridge, composite flours, bread, biscuits and other baked products. It has also been successfully investigated as a weaning food (Aloysius, 2014), and as the basis for a prebiotic nut milk (Nwinyi, 2019). Another interesting application of the flour is inclusion in noodles which was reported to enhance the nutritional composition of noodles particularly energy content, crude fat, crude fibre and carbohydrate (Hussin *et al.,* 2020).

Market Potential

Locally in Zimbabwe and elsewhere in Africa, two significant trends have the potential to fuel significant growth in demand for Bambara nuts. The first of these is for healthier foods, driven by the alarming growth in so-called lifestyle and metabolic diseases (cancer, diabetes, hypertension and anaemia). The second is for more authentically local African ingredients, rather than "exotic imported" ingredients. If prepared and presented in a modern, convenience-food format (as in the canned pro-cooked product), Bambara nuts have the potential to do well on local and regional markets. Another important opportunity lies in its use as the main protein source in supplementary feeding formulations (as a substitute for the soya bean used in the normal Corn Soya Blend formulations).

Although still little-known outside Africa, Bambara nuts were featured in the Knorr-WWF Future 50 Foods report (2019), a document that highlighted 50 underutilised foods around the world that have the potential to contribute to both healthier diets and a healthier planet. The growing demand for plant-based protein sources products creates a particular opportunity for Bambara Nut. A major constraint to this would be the fact that Bambara nuts have not been approved for consumption in the EU as a Novel Food, and would require going through regulatory approvals in a number of different markets before they could be legally adopted for use. One market study (Transparency Market Research 2020) projects steady growth in the global Bambara nut market from zero in 2020 to US$ 199 million by 2030.

Cultivation/ Domestication Potential

There is considerable local knowledge and experience of the cultivation of *V. subterranea* in Zimbabwe. Like other legume plants, it is a good soil fertiliser and a good rotation crop, being generally intercropped with cereals (maize, sorghum, and pearl millet), root and tuber crops, or vegetables. It requires warm temperatures during the growing season (20°- 28 °C), and is sensitive to extremes of temperature. It is tolerant of widely varied rainfall levels, growing in areas of annual rainfall from 500 to 1200 mm. Too much rainfall at harvest may result in yield losses. The Bambara nut can also survive in hot dry areas where other crops would not survive (DAFF, 2016)

V. subterranea does well in light sandy loams with good P and K soil content and a pH of 5.0 - 6.5 (Heuzé V *et al.,* 2016). It is propagated by seed and gives the best yields on a deeply ploughed field with a fine seedbed. Although a level seedbed is best, if wet conditions prevail it should be planted on ridges. Planting in Zimbabwe is undertaken from October to early December after good rainfall. Late planting results in poor establishment and significantly lower yields. Seed can be planted 2.5 to 3 cm deep and with a recommended spacing of 10 to 15 cm in single rows of 45 to 90 cm apart. Germination takes seven to 15 days. Earthing up (heaping of the soil up around the base of the bambara nut) after the development of flowers is found to have a positive effect on yield and also facilitate easy harvesting.

By and large Bambara nut does not require fertiliser. Excess nitrogen is known to encourage vegetative growth at the expense of crop yields. Potassium is of no value because of the strong developed tap-root system, and trials with phosphorus fertiliser have shown no beneficial effect on yield as well. Weed control is done chemically before planting, mechanically or by hand. In terms of pests and diseases, root-knot nematodes can seriously reduce yield. The most serious diseases that attack the Bambara nut are Cercospora leaf spot (Cercospora spp.), powdery mildew (Erysiphe polygoni) and fusarium wilt (Fusarium oxypolygoni). The diseases can be reduced by practising crop rotation or burning of crop debris of the previous season as well as use of resistant cultivars.

A growth period of 110 to 150 days is required for the crop to develop fully. Plants should be harvested when they turn yellow or wilt or when about 80% of the pods have matured. Seeds are mature when the parenchymatous layer surrounding the embryo has disappeared and brown patches appear on the outside of the pod. Harvesting is done by hand lifting and pulling the plant or using a groundnut harvester or hoe to cut the taproot. The nuts are then pulled off the plant, dried and stored or eaten raw.

4.23 Vigna unguiculata

Latin: *Vigna unguiculata*
Family: Fabaceae
English: Cowpea
Shona: Nyemba
Ndebele: Indumba
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical description

Vigna unguiculata, the cowpea (also known as the black-eyed pea) is a herbaceous annual legume. It is found in a variety of forms from short, bushy and prostrate, through to tall and vine-like. The upright stems are hollow and hairless, approximately 1 cm wide. The stems of twining varieties are thinner. The trifoliate leaves, which average around 10 cm long by 8 cm wide, are egg-shaped and hairless. The two lateral leaves are markedly asymmetrical while the terminal leaf is symmetrical. The plant also has extra floral nectaries, small pores on its leaves and stems of leaves that release nectar and attract beneficial insects. The branchless inflorescence produces stemmed flowers, 2.5 cm long, along the main axis. The flowers range in colour from a pale creamy white to a rich purple. Below the flower is a bell-shaped whorl of leaves. The lobes of the flower are fused, and the lateral petals are shorter than the upper petal. The seeds are borne in (8–15 cm) long, slender, round, two-valved pods growing from the leaf axils. There are between 6–20 seeds per pod growing within spongy tissue. The white, kidney-shaped seeds each have a characteristic black mark around the scar at the point where they attached to the seed stalk.

V. unguiculata is one of the oldest domesticated crops on Earth, with archaeological evidence dating its human use back to the second millennium BC. Although originating in Africa, it is now grown worldwide, especially in the tropics. It is a warm-season crop that can be produced in semi-arid regions and dry savannas. It is better adapted to sandy soils and drought conditions than other legumes like soybean (Sheahan, 2012).

Traditional Uses

Although best-known as a bean, *Vigna unguiculata* can be consumed at different stages in its development: fresh green leaves, dry leaves, green pods, green beans, or dry grain. It is known for its dual purpose in the diet of many Zimbabweans, the seed is consumed like a bean and the leaves as a vegetable (Mhlanga, 2014). The stems of the crop are also used as fodder for livestock. Cowpea is among the most popular leafy vegetable mentioned throughout Eastern and Southern Africa (Kaler *et al.,* 2005). Boiled cowpea leaves are usually served with starchy porridge, but also consumed fried or in a relish. Drying of cowpea leaves is a widespread method of preservation (Bittenbender *et al.,* 1984). In some African countries boiled and dried cowpea leaves are sometimes ground into powder and stored for use in the dry season when fresh leaves are not available.

When consumed as a bean in Zimbabwe, the seeds can be boiled together with dried maize (mutakura) or ground into a powder and cooked into a porridge (rupiza) used as relish (Matikiti *et al.,* 2012). The immature seed pods are boiled and eaten as a vegetable. Traditional West African cooking has a variety of uses for cowpeas where they are cooked with vegetables, spices, and palm oil to produce a thick soup that accompanies the basic staple (Madodé *et al.,* 2011). The seeds are also decorticated, ground into a flour, mixed with chopped onion and spices, and pressed into cakes that are either deep-fried or steamed. Some are ground or crushed into a meal that is used in buns, fritters, and sauces. Cowpea meal is also boiled, mashed, and served in puddings, porridges, and soups (National Research Council, 2006).

Cowpea is used as a forage, hay or silage. Livestock, particularly cattle, thrive on the stems and leaves left once the seeds have been harvested. Those haulms can also be dried, bundled, and stored away for the dry months when stockfeed/pastures are scarce.

Commercial History

Cowpea is grown in nearly 50 countries across the world, from Africa, the Middle East and Asia through to North and South America (Abate *et al.,* 2011) (Kebede *et al.,* 2020). An estimated 14.5 million hectares of land is planted to cowpea each year worldwide, with over 6.5 million metric tonnes produced annually. Most of the world cowpea production comes from Africa where countries such as Nigeria, Niger, Burkina Faso, Tanzania, Cameroon, Mali, and Kenya are the most important producers (Kebede et al., 2020). Cowpea is amongst the most-traded legumes by volume in Sub-Saharan Africa. It is a cash-generating commodity for farmers, small and medium-size entrepreneurs (Timko & Singh, 2008). According to Ngalamu *et al.,* (2015), trading of fresh cowpea leaves, fresh produce and processed food has provided both rural and urban communities opportunities for earning some money, particularly women.

Cowpea plays an important role in improving the livelihoods of many smallholder farmers in Zimbabwe as well. The most important production areas of cowpea are Masvingo, Manicaland, and Matabeleland North, and between 40 - 100% of the farmers growing it sell some of their produce within 12 months after harvesting (DRSS, 2016). The bulk of cowpea sales in Zimbabwe are as dried beans, with the main demand coming from informal markets in urban areas. In addition, canned cowpeas are popular in the Zimbabwean markets and are sold in several supermarkets (National Research Council, 2006).

Further commercialisation in Zimbabwe is constrained by a number of factors. Cowpea yields are relatively low, as a result of insect damage, poor management and the use of unimproved varieties. The pods shatter quite readily when mature, losing seed. Post harvest losses can be high, often as a result of attack by bruchid insects (Ngalamu *et al.,* 2014).

Potential Commercial Uses

The nutritional profile of both the seeds and leaves of *V. uinguiculata* make it an attractive food crop in Africa. It also appeals to farmers as a crop because it requires very few inputs due to the nitrogen fixing root nodules, and is well-suited to intercropping with other crops.

The primary commercial opportunity lies in the upscaling of demand for the beans. These are high in protein (approx. 25%) and very low in fat (1.5%), and are an excellent source of many key vitamins and minerals, being especially known as a key source of folic acid. They are also tasty and well-known to consumers throughout the world.

Perhaps the biggest obstacle to further commercialisation in Zimbabwe is the stigma associated with cowpeas, which are often seen as a "poor man's food". This is changing, and there is a marked consumer trend towards more authentically African foods, especially those with obvious health benefits. However, this process is made easier when cowpeas are incorporated into contemporary dishes and products appealing to high income consumers. Canned cowpeas have already proved successful, and are an example of one of the many ways to market value-added cowpea products. Cowpea flour is another that also been explored by food scientists over the years. Legume flours work as ingredients in a wide range of food products such as breads, biscuits, pasta, tortillas, and doughnuts, as well as in composite blends with foods like sweet potato and a number of cereals.

A very promising area of commercial potential comes from the leaves of the cowpea, whose protein content is exceptionally high (28 - 35%) and is on par with some famed "superfoods" (e.g. *Moringa oleifera,* with very similar protein values). The leaves (called "Munyemba" or "Imbida yendumba") are said to have a mild flavour that blends well with other dishes and are very popular with Zimbabwean consumers Being also some 30% carbohydrate and a useful source of several key minerals and vitamins, they appear to have significant growth potential, especially for communities who struggle to meet their protein requirements.

An under-explored commercial opportunity also lies in the use of the immature seed pods ("Muk-

ove"), which are usually boiled and eaten as a vegetable (National Research Council, 2006). These have similar nutritional properties to the dried seeds, but with the added benefit of lower levels of some of the antinutritional properties found in the dry seeds.

There is also much greater potential for cowpea to be commercialised as a fodder crop. Indeed, its use as livestock feed is probably responsible for its name 'cowpea'. Cowpea pastures are well developed in Asia and Australia where it is considered an annual forage whose quality is at his best during summer and autumn (Tarawali *et al.,* 1997). Used with maize, it is a high grade forage for pigs and sheep. In West Africa, cowpea hay is an important fodder sold in local markets. In smallholder systems, when used as a dual-purpose legume, cowpea hay can be used as animal feed. Well-cured cowpea haulms are a useful feed and can make excellent hay, provided that the leaves are well preserved (Heuze *et al.,* 2015).

Market Potential

There seems little doubt that demand for *V. unguiculata* will experience steady growth in the coming years (Market Data Forecast, 2020). The global trend away from meat and towards plant-based sources of protein, combined with a growing local awareness of the health benefits of a more traditional diet, will drive this growth. There are already cowpea ingredients being produced by companies from around the globe to cater to vegans and other diet enthusiasts (Transparency Market Research, 2020). In addition, manufacturers of bakery, snacks, and confectionery products require plant-based ingredients to enhance texture, flavour, aroma, appearance and nutritional profile of their products. Market researchers are projecting that the global cowpea market will reach US$10.5 billion/yr by 2030 (Transparency Market Research, 2021). This will also create multiple opportunities for value-added cowpea products.

Within Africa there are countries, like Nigeria, Ghana and Cote d'Ivoire, where cowpea demand outstrips local supply, creating intra-regional export opportunities. In addition, school feeding programs are on the rise in Africa and many governments are increasingly sourcing food for school feeding locally from smallholder farmers in order to boost local agriculture (Fominyen, 2019). This is a major market opportunity for smallholder cowpea farmers.

Grass/legume mixtures for forage have excellent growth potential, especially in the dairy farming sector. Forage production is not dependent on pastures and forage crops alone, as crop residues also make an important contribution in integrated crop/forage production systems.

Overall the cowpea value chain in Zimbabwe has considerable opportunities for advancement. If more industrial-scale processing were to take place, this would in terns create more room for players all along the chain, with greater levels of organisation and co-ordination and more attractive returns at the end.

Cultivation/ Domestication Potential

Cowpea was domesticated in Africa and is currently widely cultivated in many parts of the world. It grows best during summer, with optimum temperatures between 8.5° C and 30° C for growth and development (DAFF, 2011). The optimum sowing times in Southern Africa are December to January. The presence of nodular bacteria specific to

cowpea (Bradyrhizobium spp.), make it suitable for cultivation in the hot, marginal cropping areas of Southern Africa. Cowpea is a drought-tolerant crop that does well in rainfall between 400 and 700 mm per annum. It also tolerates waterlogging, but well-distributed rainfall is important for normal growth and development.

Cowpea can grow on a wide range of soils but shows a preference for sandy soils, which tend to be less restrictive on root growth. It is more tolerant to infertile and acid soils than many other crops, and responds well under conservation agriculture. Both inter-row and intra-row spacing will be determined by the type of variety and growing pattern. More space between plant and rows will be required with trailing types relative to the upright growing pattern. Generally for grain production, a plant population of 200 000 to 300 000/ha at 30 to 50 cm inter-row spacing is preferred. For optimum yield, cowpeas should be planted late November to early December. Fertiliser application in cowpea production depends on anticipated yield and soil fertility. As a legume, cowpea fixes its own nitrogen, and does not need nitrogen fertiliser. Seed should be inoculated with the appropriate Rhizobium species for optimum nitrogen fixation, however nodules will generally form on cowpeas. Application of a phosphate fertiliser is usually beneficial.

Cowpeas are usually grown under dryland rather than irrigated conditions. Annual grasses and some broadleaf weeds can be controlled by a pre-sowing application of herbicide. Hand weeding of the infested areas before Striga sets seeds is the most important control method at present. Cowpea is very attractive to insects. Insect pests have remained the most important setback to cowpea production, because each phase attracts a number of insect pests. Control by one or two applications of insecticide is invariably necessary. For commercial production this will lead to downgrading of grain. Control should only be considered where large infestations are threatening the crop or when viral infections have been observed. Leaves can be harvested from 4 weeks after planting to the onset of flowering. Harvest pods when they are relatively dry and thresh when completely dry.

4.24 Ximenia caffra

Latin: *Ximenia caffra*
Family: Olacaceae
English: Sour plum
Shona: Munhengeni
Ndebele: Umthunduluka
Regions in Zimbabwe: Zambezi, Kalahari, Central, Save-Limpopo

Botanical description

Ximenia caffra is a deciduous, sparsely branched shrub or small tree that grows up to 6 m tall with an open crown. Branches and twigs are armed with stout axillary spines. The bark is dark grey and rough, but pale green or brown on younger branches. Sapwood is white and heartwood is hard and reddish brown. The root system is non-aggressive. The leathery dark green leaves are often in clusters (fascicles) on short, spur branchlets. They are simple, alternate, elliptic to lanceolate, 2.5 - 9 cm long by 1.2 - 5 cm wide, with margin entire, apex rounded or notched, the base broadly tapering to rounded and the petiole about 8 mm long. There are two varieties of *X. caffra* which can be distinguished by the degree of hairiness of the leaves. *Ximenia caffra* var. *caffra* has dense reddish hairs on the leaves and branchlets, whereas var. *natalensis* has smooth leaves.

The flowers are small, sweet-scented and greenish to creamy-white and borne from August to October in single-stem clusters in the axils of the spines or on the dwarf branchlets. Fruits are thinly fleshy, oval, attractive fruits (drupes) which are 25 mm long and a glossy, deep red colour with distinctive white spots. Seeds are smooth, ellipsoid, yellowish-brown to red, up to 2.5 cm long, 1 cm thick and hard coated (Baloyi and Reynolds, 2004).

The tree species is commonly found in dry wooded bushland and wooded grassland especially on rocky hillsides and termite mounds, but is more abundant in coastal and lowland dry woodland. The common associate tree species are *Vachellia tortilis, Afzelia quanzensis, Brachystegia spiciformis, Grewia bicolor, Gymnosporia senegalensis, Terminalia sericea,* among others. In Zimbabwe it occurs in four ecological regions (World Agroforestry Centre, 2021).

Traditional Uses

There are many traditional uses associated with *X. caffra.* The fruits are eaten raw and, though bitter or sour, they have a refreshing taste and an almond-like scent. Alternatively they are soaked in cold water, the skin and kernel are removed by pressing them out and the resulting porridge is mixed with pounded tubers, which is then eaten. The fruits are also suitable for preparing jam (Baloyi and Reynolds, 2004).

The seeds/ nuts are sometimes eaten but are more highly valued for their oil which is used as a moisturiser, a soap and a shampoo for dry, fragile and damaged hair (Maroyi, 2016). The roasted seeds are mashed in a mortar yielding a viscous, non-drying oil which is applied to colour the hair to dark black and helps to straighten it. The Khoi-San use the oil as a skin conditioner, and to treat chapped hands and feet (Van Wyk *et al.,* 1997). The oil is traditionally used to soften animal hides. It is also used as a fuel for lamps.

X. caffra is also widely used in Africa as traditional medicine (Maroyi, 2016). A decoction from the leaves is used as a wash to soothe inflamed eyes. Infusions of the roots are consumed as a remedy for dysentery and diarrhoea and, together with the leaves, are taken for abdominal, pain and bilharzia. Powdered roots are applied to sores to speed up healing; used in soup, and in beer as an aphrodisiac. Powdered dried leaves are taken orally for fever and infertility, and extracts of the leaves are used as a gargle for tonsillitis, and as a vermifuge. A porridge is made using a decoction of the roots and eaten once a day for nausea in pregnancy. The root decoction is also taken for infertility (Baloyi and Reynolds, 2004). The roasted and pounded seeds are used for wounds.

Finally, *X. caffra* is often domesticated and grown as an ornamental plant and/or a live fence (World Agroforestry Centre, 2021).

Commercial History

The primary commercial application of *X. caffra* has been the use of its seed oil (usually referred to simply as "Ximenia oil") (Future Market Insights, 2018). In Zimbabwe, there are a number of small to medium enterprises processing Ximenia oil for both the local and international market. Although no information is available on the volumes of trade in Zimbabwe, there are several brands on the local market using Ximenia oil in various restructuring and anti-ageing hair care and/or skincare formulations (Nair *et al.,* 2013).

The main commercial trade in Ximenia oil has come from Namibia, where a significant number of SMEs are engaged in processing and marketing Ximenia oil. Traditional Ximenia oil can be found, with other indigenous plant products, in open markets throughout the north-central regions of Namibia and further south in the urban centres. The oil is highly valued as a hair care ingredient and is used to condition the scalp and restore heat-damaged hair. Efforts to bring it on to the export market were initiated in the early 2000s by the trade association PhytoTrade Africa and, after the oil was assigned a formal INCI name (International Nomenclature of Cosmetic Ingredients) in 2003, a growing export demand has arisen from international cosmetic companies. Today Ximenia oil is well-known to the cosmetics industry around the world, particularly for its role as an active ingredient in anti-ageing formulations.

Potential Commercial Uses

By far the greatest commercial potential for the sour plum comes from its oil. Ximenia oil is rich in unsaturated fatty acids (~ 92%), and therefore has considerable nutritional value (Van Wyk et al., 1997). Furthermore, its long chain fatty acids make the oil unusually viscous, with a silky-smooth feeling when applied to the skin. One of these fatty acids, Ximenynic acid (named after the tree) is especially prized in the cosmetics industry for its skincare properties. These include the fact that it stimulates micro-circulation through vasodilation and acts is a potent topical anti-inflammatory (by both inhibiting Phospholipase A2 activity on neural cell membranes and inhibiting Leukotriene B4).

Currently the oil is extensively used as a skincare ingredient to help smoothen, hydrate and increase skin elasticity, as well as to prevent stretch marks in pregnant woman. Applications include baby skin protection, moisturising, intensive dry skin treatment, skin disorders and anti-wrinkle formulations. It is also useful in treating skin disorders such as scars, eczema, acne, scars, blemishes, and rough spots. Ximenia Oil can also be used to formulate hair care products such as hair moisturisers, hair conditioners, and hair styling products, and is known to stimulate hair growth and condition the scalp (Future Markets Insights, 2018).

Some research has been undertaken on the use of the oil as a health food ingredient. Ximenynic acid is known to have potential in helping to regulate body weight, preventing or treating insulin resistance or related disorders, improving memory function and delaying the onset of Alzheimers, lowering blood lipid levels and helping prevent cancer. A 2004 patent application to produce pure powdered Ximenynic acid from Ximenia oil was eventually dropped, presumably for technical reasons, but the commercial potential still undoubtedly exists.

In addition to all the mentioned potential uses, the oil can be used as a domestic biofuel and for softening leather such as leather boots and skirts (Kibuge, 2014). The fruits which are high in vitamin C, protein and potassium value and are used for making preserves such as jam and jelly (Van Wyk and Gericke, 2000).

Market Potential

The commercial properties of Ximenia oil are highly attractive to the cosmetics industry, and export demand for the oil in the cosmetics market is ro-

bust and growing steadily. The main constraint to more rapid growth is the fragility and unreliability of supply. At the moment, all Ximenia oil in the market is supplied from wild-harvested sources and this is perceived as a risk to buyers, particularly because the tree is not found in any significant population concentrations but is instead thinly scattered over a wide area. This creates a major opportunity for any suppliers investing in the commercial growing of *X. caffra*. Reliable, large-scale Ximenia oil producers are likely to be well-received by the export market and would almost certainly unlock multiple new growth opportunities.

Even though the main outlet for Ximenia oil is through exports, there is also considerable potential for growing the local market. Although small, the local market is high value. There are many opportunities for growing demand as consumers are becoming more aware of the potential of indigenous products and their benefits and are also moving towards more environmentally-friendly skin and hair care products. The trend amongst Zimbabwean women towards wearing their natural hair also stimulates demand for new hair care products such as Ximenia oil (Sithole, 2020). According to Future Market Insights (2018), Zimbabwe is one is one of the top global producers of Ximenia oil among other countries such as Namibia, Botswana and South Africa; this makes the oil a unique product which can also marketed in other parts of Africa.

In addition to the pure oil, there are also several value addition opportunities around Ximenia oil. Examples include investing in simple technologies to concentrate the percentage of Ximenynic acid, refine the oil to extend its shelf-life, reduce the microbial load through e.g. centrifugation and incorporate the oil into synergistic blends with other indigenous oils (e.g. marula oil) to enhance biological activity.

Cultivation/ Domestication Potential

Although *Ximenia caffra* has not been domesticated in Zimbabwe, it has a potential to be cultivated on a large scale. Propagation of X. caffra trees has the potential to increase harvesting quantities and reduce the harvesting effort of collecting fruits from distant trees that need to be visited regularly throughout the fruiting season. Propagation is also necessary to counteract bad harvesting years, which could be a threat to commercialisation of the species.

Ximenia caffra has good seed germination capacity and profuse natural regeneration, but saplings may succumb to prolonged drought or forest fires. Partial protection of natural woodland could help promote regeneration. It is easily cultivated from fresh seed with a mixture of river sand and compost (5:1). Ximenia can be propagated either in sand, sawdust or sand/sawdust media (Owuor *et al.,* 2009). Application of NAA (□-Naphthallic acetic acid) hormone also increases the rate of root growth. The seeds germinate after 14-30 days and transplanting should take place when the seedlings reach the two-leaf stage. *X. caffra* is partly parasitic, and will grow better once in the ground where it can make contact with other plant roots. The growth rate is moderate, up to 0.5 m per year; it can withstand moderate frost and is drought-resistant, but it requires full sun (Baloyi and Reynolds, 2004).

4.25 Ziziphus mauritiana

Latin: *Ziziphus mauritiana*
Family: Rhamnaceae
English: Jujube
Shona: Masau
Ndebele:
Regions in Zimbabwe: Zambezi, Kalahari

Botanical description

Ziziphus mauritiana is a spiny, evergreen shrub/tree which grows up to 15 m in height, with a trunk 40 cm or more in diameter. It has a spreading crown, stipular spines and many drooping branches. The irregularly fissured bark is a dark grey or dull black colour. Where climatic conditions are severe, it is commonly a compact shrub only 3-4 m tall. The leaves are variable, alternate, in 2 rows and oblong-elliptic, 2.5-6 x 1.5-5 cm. Tips are rounded or slightly notched, and the leaves are prominently 3-veined from the base. They are finely toothed on edges, shiny green and hairless above, but with dense, whitish, soft hairs underneath. The inflorescences have axillary cymes which are 1-2 cm long, with 7-20 flowers. The peduncles are 2-3 mm long and the flowers 2-3 mm across, greenish-yellow, faintly fragrant and with 5 petals. The fruit is a drupe, globose to ovoid, up to 6 x 4 cm in cultivation, usually much smaller when wild. The skin is smooth or rough, glossy, thin but tough, yellowish to reddish or blackish. The flesh is white, crisp, juicy, subacid to sweet, becoming mealy in fully ripe fruits. Seed is a tuberculate and irregularly furrowed stone, containing 1-2 elliptic brown kernels each 6 mm long (Orwa *et al.,* 2009).

The species grows naturally in hot and dry areas throughout the tropics, with a natural range extending from Senegal across to Tanzania and Somalia, and then through into India and South-East Asia. It is not strictly native to Zimbabwe, although it is locally abundant where it is found in the Zambezi region. It is believed to have been introduced to Zimbabwe several hundred years ago by slave traders travelling upstream from the coast along the Zambezi river.

Traditional Uses

Jujube (masau) fruit are a popular edible fruit in Zimbabwe, and at the time of harvest it is a common sight to see truckloads of the fruit being brought into urban areas from the Zambezi valley to be sold on local markets or by roadside vendors. The fruit are eaten fresh or dried and can be made into a floury meal, butter, or a cheese-like paste, used as a condiment (Fern, 2019). They are also suitable for making confectionary and for pickling, and are often used in chutneys, jams and preserves. A refreshing *mahewu* drink is prepared by macerating fruits in water, and the dried fruits are sometimes pound into a flour and used to make a herbal tea. Wherever *Z. mauritiana* is found around the world, the fruits are eaten and made into a variety of different locally-specific food products. In China they call the fruit "Chinese dates" or "red dates" and eat them dried and sliced. In India they are called "ber" and are eaten fresh. To the rest of the world they are called jujube.

Perhaps even more popular than the fresh fruit are the alcoholic beverages made from masau fruits. A wine is made by soaking the fruits overnight and leaving them to ferment for several days at ambient temperature. This wine is then used as the basis for a distilled beverage called *kachasu.* This potent brew is much prized by its fans, and large areas of the sandy Mukuvisi river in Harare are used as the location for the operation of illegal *kachasu* stills. This use is reflected in many other countries. In Malawi, a wine called *mlunguzi* is produced from a combination of *Uapaca kirkiana* and *Z. mauritiana* (Maghembe *et al.,* 1992), and has been marketed commercially through formal channels. In Italy there is a masau liquor called Brodo di Giuggiole, and in China there is a distillate called "baijiu" as well as a brandy popular in the Taihang Mountain districts of Hebei.

There are many other traditional uses for jujube products. In India a functional vinegar is made from the fruit, and consumed as a health product. Candied jujube is a popular confectionary in China. In some parts of India and North Africa, the leaves of Z. mauritiana are harvested as nutritious fodder for sheep and goats or gathered to feed tasar silk-

worms. The drooping branches make the leaves easily accessible for harvesting. When in bloom, the tree is a good source of pollen and is used for apiculture. *Z. mauritiana* is also used as timber and it yields a medium-weight to heavy hardwood. The wood is used for general construction, furniture and agricultural implements. The bark, including the root bark, has been used in tanning and, when pounded and mashed in water, it yields brown and grey or reddish dyes. In Ethiopia, *Z. mauritiana* is used to stupefy. Pounded roots are added to drinking water and given to poultry suffering from diarrhoea and to humans for indigestion. In India, *Z. mauritiana* trees are a host for the lac insects, Kerria lacca, which are found on the leaves and make an orange-red resinous substance (Orwa *et al.,* 2009). The purified resin makes the high-quality ber shellac that is used in fine lacquer work and to produce sealing wax. The species is useful as a living fence; its spiny stems and branches deter livestock.

Commercial History

Masau plays a critical role in the rural economy for communities in areas where the tree is found. In Zimbabwe the fruit ripen from May to August, during the agricultural off-season, and their sale and marketing provides much-needed income at a time when alternative income sources are limited. Commercial trade of masau fruit from the Zambezi Valley to Harare and other urban centres has been ongoing since the 1980s (and probably earlier). Although much of the value is captured by middle-men, who bring transport into the harvesting areas and buy fruit directly from the farmers, the scale of the industry is significant, and there are districts in Zimbabwe where levies on trucks ferrying fruit are a major revenue source for the Rural District Councils. The fruit are sold in the fresh fruit markets, as well as being purchased by roadside vendors for resale in other areas. Much of the fruit is purchased for distillation of *kachasu* which, although illegal, remains one of the most enduringly popular moonshine beverages in Zimbabwe.

The first attempts to bring masau products on to the formal market in Zimbabwe arose as a result of a partnership between the NGO SAFIRE and the private company Speciality Foods of Africa, through its brand Tulimara. This resulted in the production and launch of a masau jam on to the domestic market in the late 1990s, followed by experimental product launches of various confectionaries (including a popular but short-lived chocolate-coated masau fruit) and herbal tea blends.

In the early 2000s, an attempt was made to begin distilling a masau liqueur in Zimbabwe for launch on to the formal market, sadly thwarted by prevailing unfavourable economic conditions at the time. However, the rising popularity of *mahewu* on the local market since 2010 has seen many *mahweu* manufacturers experimenting with masau flavours. Masau fruit are occasionally seen in supermarkets and masau products make seasonal appearances on some restaurant menus.

Elsewhere in the world, *Z. mauritania* fruit are the basis for many large-scale industries, mostly around fruit products and beverages (especially in India and China). Jujube has regulatory approval for sale in the EU and the US, and jujube products can be found in health stores and online selling platforms around the world. There are over 90 different cultivars of jujube in India, and the country produces over 1 million tonnes of the fruit per year (Janick *et al.,* 2008).

Potential Commercial Uses

The commercial potential for *Z. mauritiana* fruit in Zimbabwe closely follows the trajectory of commercial development in other parts of the world. The fruit pulp has high sugar content (sucrose, glucose fructose and starch) and protein with many essential amino acids like asparginine, arginine, glutamic acid, aspartic acid, glycine, serine and threonine (Neeraj and Bisht, 2019). It also contains good amounts of vitamins A, B complex and C in comparison to other fruits, and is high in calcium and phosphorus. It makes a nutritious, tasty and versatile fruit that can be used in a wide range of commercial food applications.

In terms of value addition, the quickest and easiest markets to pursue would involve drying the fruit and then incorporating the dried fruit powder into various different food products. Masau has already experienced some success in *mahewu* products, but a specific masau-based *mahewu* product shows considerable potential. Other forms of beverage premix would also work with the powder, as would herbal tea formulations. The powder goes well in confectionaries and baked goods, and is already used in a traditional bread loaf in the areas where it occurs. The fruit make excellent jams, jellies and preserves, and would do exceptionally well in the burgeoning market for chilli sauces.

Alcoholic beverages are another obvious market opportunity, considering both the rapid growth in these markets and the fact that masau is already traditionally used to make a highly tasty kachasu spirit. Incorporating masau fruit into a craft gin, a brandy or a schnapps product.

Market Potential

Compared with the 1 million tonne/yr jujube fruit production in India, it seems unlikely that Zimbabwean producers could be competitive on an export market. However, the local and regional market opportunities for masau fruit are large enough to justify sustained investment.

The growing demand on the local market for non-alcoholic fruit beverages as alternatives to carbonated soft drinks has seen an explosion of new product launches from *mahewu,* fruit cordials and fruit-flavoured dairy drinks through to fermented kombucha-type drinks, iced teas and fruit smoothies. Health-conscious consumers are looking to move away from synthetic ingredients and drinks with high added sugar content. The trend is instead towards beverages that taste good and offer obvious health benefits. The Zimbabwean formal carbonated beverage market averages around USD 200 million/yr, but the informal market may be much larger.

Specialty food markets are also growing, with Zimbabwean consumers keen to "return to their roots" and try out ancestral, heritage foods, many of which are perceived to be healthier and more natural alternatives to the processed food that dominates food sales in urban areas. The growing number of restaurants that serve traditional food, and the ever-increasing size of the supermarket aisle that specialises in traditional foods, are all testament to the latent demand in Zimbabwe.

The one export product that might be feasible from Zimbabwe using masau would be a high quality alcoholic beverage. The global craft spirits market is growing at a remarkable 33% a year and is projected to reach USD 80 billion/yr by 2025 (Grand View Research 2020). The demand is underpinned by growing consumer interest in premium and authentic drinks with unique flavours and strong marketing stories. The largest share of consumers is made up of people born between 1980 and 2000 (the so-called millennials) who have a markedly different taste to their preceding generation. Millennials prefer unconventional and experimental beverages, and are often as concerned with the story behind their conception and manufacture as they are with the flavour and ingredients used. A craft masau spirit, incorporating a strong back story relating to the Zambezi valley and its provenance, could be a winning combination.

Cultivation/ Domestication Potential

Jujube is a hardy tree that copes with extreme temperatures and thrives under rather dry conditions. The possibility of domesticating this species has been explored and it has been successfully domesticated in Zimbabwe and other countries like India where it is grown on a commercial scale (Palejkar *et al.,* 2012). *Z. mauritiana* is a fast-growing species. Under favourable conditions, height increment on loose soil is 75 cm in 1 year and 1.2 m in 2 years (Orwa *et al.,* 2009). *Z. mauritiana* tolerates a wide range of temperature from -5°C to 49°C and annual rainfall in its natural habitat ranges from 125 to 2225 mm. There are no specific soil requirements for *Z. mauritiana,* but deep sandy to loamy soils of pH<9 are considered best for optimum growth (CABI, 2019). It also adapts well to rain-fed agriculture on black cotton soils due to its strong and deep root system

Fruit flies are a major cause of crop losses, the insects unfortunately having a preference for the same cultivars as humans. Damage by fruit-borers, leaf-eating caterpillars, weevils, leafhoppers and mealy bugs has also been reported. Powdery mildew can be so serious that leaves and fruitlets drop, but it can be adequately controlled (Orwa *et al.,* 2009). According to a study by Ibrahim et al (2015) dry land plantations of *Z. mauritania* can guarantee a reasonable harvest especially when using the right varieties and rootstocks.

section 5: Discussion of the potential for indigenous plants to contribute to the growth of the Zimbabwean agricultural sector, and broader opportunities for the development of a national Bio economy strategy.

5.1 The Historical Role of Indigenous Plants in Zimbabwean Agriculture

Although Zimbabweans have always had a close relationship with indigenous plants, the nature of that relationship has changed over time. In pre-colonial times, plants were the basis of almost all economic activity in the country (except for mining) and provided a reliable and predictable source of food, medicine, building materials, fuel, fodder and other tangible goods. They also provided a range of less tangible, but no less essential, ecosystem and environmental services, including catchment protection, shade, soil conservation, windbreaks, carbon sequestration, wildlife habitat and others. At this stage the relationship of people to plants was one of deep interdependence, strongly underpinned by a set of spiritual beliefs in which plants played a central role.

The advent of colonialism brought a more functional approach towards indigenous plants. The formal discipline of economic botany was first recognised in Zimbabwe with the establishment of a national herbarium in 1909. Thus began a period of sustained and systematic exploration of the economic potential of indigenous plants. Many fortunes had been built in other parts of the world around indigenous plants, including rubber, quinine, cocoa, timber and others, and there was every reason to believe Zimbabwe offered similar opportunities. Gradually, however, research attention turned towards the more immediate economic returns to be made from a handful of already globally commoditised, non-indigenous cash crops. The first tobacco research centre was established in 1924, followed by similar investments in the development of cotton, maize, wheat, coffee, groundnuts, sugar and soya beans. Very quickly a large and successful commercial agricultural sector grew up around these crops and research interest in indigenous plants declined.

It was not until the 1990s that renewed interest began to be shown in the economic value of indigenous plants. There were two key drivers for this. The first was the crippling drought of 1991, which showed the folly of depending entirely on crops from other parts of the world, evolved to suit different climatic conditions to those pertaining in Zimbabwe. There was an almost total crop failure across the country, and yet the majority of indigenous plants survived.

The second was an opening up of Zimbabwe's borders to imports as a result of the IMF-led Economic Structural Adjustment Programme, leading to flood of cheap imports that forced many local businesses to the brink of bankruptcy. Suddenly it no longer made sense for local farmers to grow crops that could be imported more cheaply from other parts of the world. Researchers began once again to look at the opportunities from growing and harvesting indigenous plants, plants that can withstand the periodic cycles of drought to which Zimbabwe is becoming ever more prone, and plants that are not grown at lower cost and in larger volumes elsewhere in the world.

5.2 The Cost of Ignoring Indigenous Plants

Although the short term gains from the shift towards exotic cash crops cannot be overlooked, the longer term costs of ignoring the potential of indigenous plants have been substantial and are played out in many different spheres.

5.2.1 Poor Diet

Whereas previously Zimbabwean consumers enjoyed a diverse diet of traditional crops and wild-harvested fruits and vegetables, now they are funnelled into a very narrow range of food crops (based predominantly on exotic food crops that are not native to Zimbabwe). The 2020 ZIMVAC assessment found that only 31% of rural Zimbabwean households consume a diet defined as "acceptable", with 39% "borderline" and a full 30% reported as "poor". The key missing factor is diversity. This reflects global trends where, despite the fact that we have over 50,000 edible plant species in the world, we derive 60% of our nutritional input from just three species (rice, maize and wheat).

WHO guidelines for a healthy diet stress the importance of eating a variety of different whole (i.e. unprocessed) and fresh foods every day. Although the traditional diet in Zimbabwe was historically

very diverse, the modern diet is not. Furthermore, substantial investments in marketing a narrow range of foods have resulted in changes to consumer preferences, with many consumers actively preferring foods that are high in sugar, fats and salt, leading inevitably to a rise in the prevalence of Non-Communicable Diseases (diabetes, heart disease, strokes and cancer).

5.2.2 Reduced Resilience

Historically farmers grew a diversity of different indigenous crops and supplemented their food and income with wild-harvested plant resources. This gave them a robust resilience to adverse climatic events (drought, frost, hail) and pest outbreaks. Indigenous plants, having evolved in our climatic conditions and alongside our natural pests, are much more able to withstand periodic shocks than exotic crops. However, many farmers today rely on only one or two crops, usually ones that are not originally from Zimbabwe and not adapted to our conditions and are therefore highly vulnerable to periodic shocks leading to partial, or even total, crop failure.

5.2.3 Soil Erosion, Land Degradation and Biodiversity Loss

Traditional rural production systems in Zimbabwe were supportive of, and indeed largely based upon, local biodiversity. The mutual interdependence of people and nature meant that natural ecosystems were protected and sustainably managed for the benefit of all. Today, Zimbabwe is losing an estimated 330,000 hectares of indigenous forest and woodland a year (Sixth National Report to the CBD 2020). The single largest cause of this biodiversity loss is agricultural expansion. Indigenous trees and plants are cleared to make way for arable crops, predominantly of exotic origin, often grown in a monocultural plantation. The negative impacts of this industrialised farming model on biodiversity and ecosystem integrity are multiple and, especially in the dryland areas of the country, lead inevitably into an ever-tightening spiral of poverty and land degradation.

5.2.4 Commodity Dependence

Historically, Zimbabwe had a diverse rural economic production system, based on a variety of indigenous plant resources, to many of which value was added locally, and prices for which were largely determined by local producers. The switch away from this towards crops that do not naturally occur in Zimbabwe has created a vulnerability and dependence amongst Zimbabwean farmers on commodity markets and pricing models that are entirely outside their control (86% of Zimbabwe's export earnings being derived from commodities, making it one of the most commodity-dependent countries in the world – UNCTAD 2019). This heavy dependence makes the Zimbabwean economy highly vulnerable to shocks and price fluctuations.

5.2.5 Cultural Erosion

Many of the activities associated with harvesting and preparing indigenous plant-derived foods and products are central to the cultural norms and values of rural Zimbabwean society. The move away from these has reinforced the progressive erosion of traditional cultural values, with all of the associated problems this brings. These problems include the breakdown of the social safety net provided by the extended family network, loss of respect for the knowledge and wisdom of the elders, and loss of centuries of accumulated scientific know-how relating to plant use and plant medicine.

5.2.6 Loss of Food Sovereignty

Food sovereignty is defined as the "right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems". Ignoring indigenous plants has divested Zimbabweans of this right, and has instead allowed large corporate players in the food industry to become the key determinants of what people eat and how it is produced in Zimbabwe.

5.3 The Bioeconomy

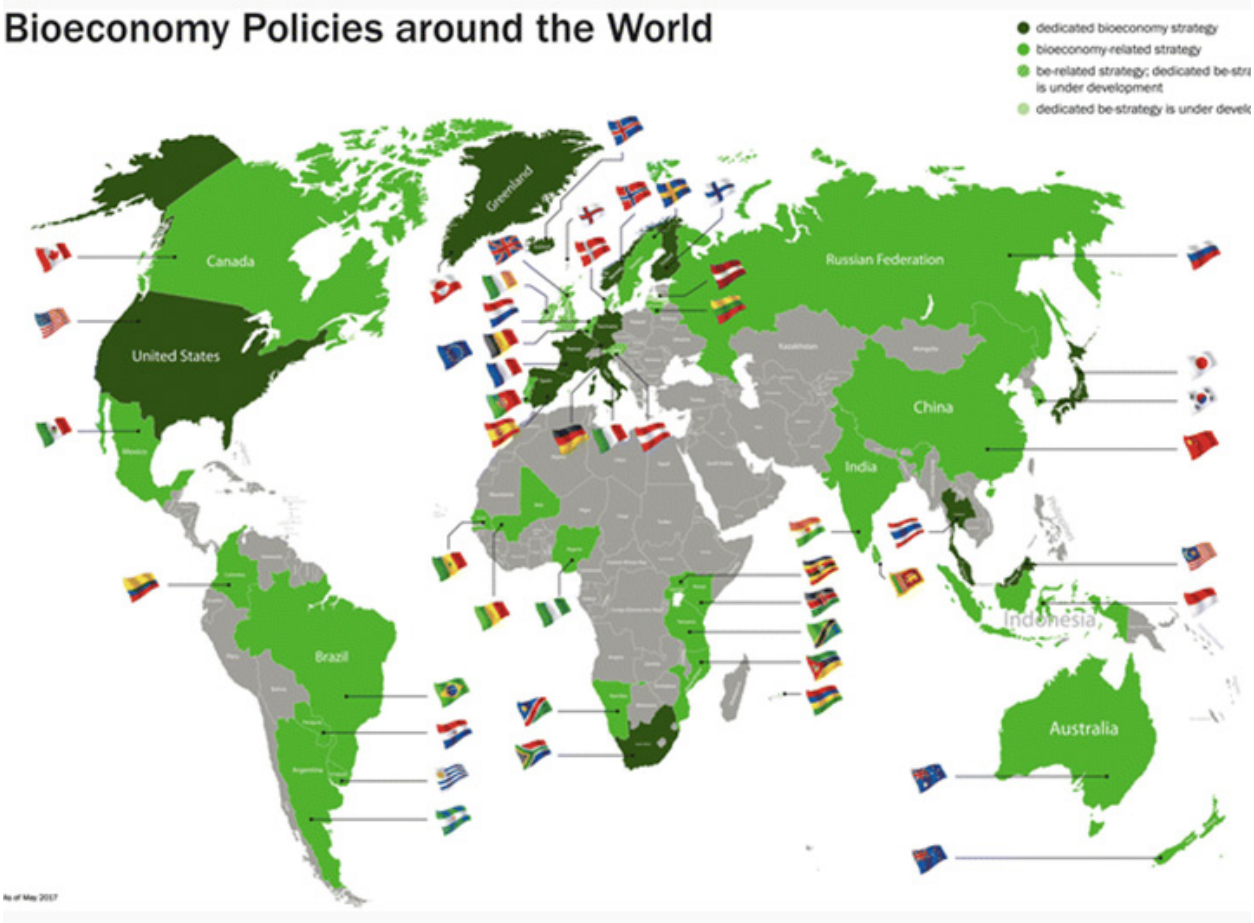
The notion of the Bioeconomy has risen to prominence since 2010, driven by growing concerns about the impact of fossil fuel dependence on climate and economic stability, and a desire to harness the full capabilities of 21st Century science and technology to achieve more sustainable growth models for the future of our planet. Although there is no single definition of the term "Bioeconomy", and countries that have adopted Bioeconomy strategies vary significantly in their individual interpretation to suit local conditions, most agree with the broad definition from the first ever Global Bioeconomy Summit in 2015 as follows:

….the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors.

By 2020, there were 19 dedicated national and mac-

ro-regional Bioeconomy policy strategies in place around the world, and several more under development (see Figure 1). Of particular relevance to Zimbabwe are the strategies under active development and/or implementation in South Africa, Namibia and the East African community. For most of these countries, the Bioeconomy is seen as an important driver of economic growth and job creation. Bioeconomic solutions are also increasingly valued for their contributions towards achieving the Sustainable Development Goals. In addition to this, recent policy documents view the Bioeconomy as a new strategy for reindustrialization and for coping with changing global political contexts and challenges, such as the Covid-19 pandemic, fostering resilience, combating zoonotic and epizootic diseases, and biodiversity issues.

Figure 1: Countries with Bioeconomy Strategies in use or under development by 2017



SOURCE: BÖR (2017) Bioeconomy policies and strategies established by 2017. Diagram prepared by the German Bioeconomy Council (Bioökonomierat – BÖR), Berlin

Although the Bioeconomy cuts across a wide range of economic activities, the sectors with perhaps most relevance to Zimbabwe are as follows:

- Agriculture: sustainable intensification, improved yields, crop diversification, enhanced resilience, reduced emissions, adaptation to climate change and biofuel production.
- Health: improved diet, drug discovery and bioprospecting, herbal remedies for primary health care, phytomedicine and nutraceutical development and manufacturing.
- Industry: local value addition, industrial biotechnology, innovations around biomaterials, the circular economy, improved waste management, water use and waste-water treatment, decarbonization of production and consumption.

5.4 Indigenous Plants in the Bioeconomy

The Bioeconomy is the sustainable and innovative use of biological resources and knowledge to provide food, feed, industrial products, bioenergy, and ecological and other services towards economic growth. As one of the most abundant and immediately exploitable of these biological resources, indigenous plants will inevitably play a major role in the growth of the Zimbabwean Bioeconomy. Specific linkages to the Bioeconomy include the following:

5.4.1 Indigenous Plants and Agriculture

The Bioeconomy will see a sustained investment in identifying and developing indigenous plants that have commercial potential for farmers. These investments will focus on cultivation and domestication, improved varieties and yields and mixed production systems that involve a diverse range of crops. Investment will be driven by competent and well-resourced sector support organisations. All production will be based on the principles of conservation and regenerative agriculture. A major focus of investment will be on unlocking the regulatory hurdles towards market expansion for these products, enabling Zimbabwean farmers to access new markets and market opportunities for indigenous plant products around the world. There will be a strong emphasis on products that enhance resilience in the face of climate change and significant research attention will be focused on the use of indigenous plants for biofuel.

5.4.2 Indigenous Plants and Health

The Health sector in the Bioeconomy will spearhead a drive to reintroduce traditional foods and innovate with new foods based around indigenous plants, aimed at improving the dietary diversity of Zimbabwean consumers and stimulating demand for farmers. A major locus of investment will be the development of a systematic drug discovery and bioprospecting programme focused on indigenous plants. The intentions would be to identify novel phytomedicines with global commercial value and develop supply chains from Zimbabwean farmers to deliver the required raw materials. A spin-off from this will be an initiative to identify, validate, approve and disseminate a range of herbal remedies based on indigenous plants for use at a primary health care level country-wide. This would be undertaken in close collaboration with Traditional Medical Practitioners. A secondary spin-off would be the development, manufacture and nationwide promotion of a range of nutraceutical products based around indigenous plants.

5.4.3 Indigenous Plants and Industry

The Bioeconomy will be a key instrument of reindustrialisation for Zimbabwe, driving growth and job creation and positioning the country as a knowledge-based, middle income economy. A major focal area will be on value addition opportunities for indigenous plants, engaging in advanced agro-processing and the manufacture of, amongst other things, novel food and beverage products, biofuels, phytomedicines, nutraceuticals, natural cosmetic and personal care products. Priority will be given to import substitution and developing new export industries. Advanced biotechnology will be used to produce a range of climate-friendly biomaterials from indigenous plants as the foundations of a revitalised manufacturing sector. Sustained attention will also be given to the role of indigenous plants in achieving circularity and decarbonisation through the development of biofuels, beneficiation of biomass waste and the adoption of innovative biocatalysis technologies.

5.5. Benefits to Zimbabwe from Investing in Indigenous Plants and the Bioeconomy

5.5.1 More sustainable and resilient agricultural production system

Indigenous plants require less agro-chemicals than other crops, and are both more nurturing of the soil and more resilient to climatic variations than other crops. The outcome of integrating more indigenous plants into a diversified and regenerative agricultural production system will be a much stronger and more robust agro-economy. Key elements of this will be healthier soils and associated agro-ecosystems, reduced carbon emissions, improved sustainability of resource use, greater resilience in the face of climatic and market shocks, higher levels of employment and a healthier and more productive labour force.

5.5.2 Healthier population

A focus on producing and consuming more indigenous plant-based foods, beverages and medicines will result in a healthier population. The diet will become more diverse, with a move towards foods that are lower in sugar, fats and salt and of improved nutritional value. The prevalence of Non-Communicable Diseases and other nutritionally-derived conditions (e.g. stunting) will go down. Widespread use of locally produced herbal remedies and phytomedicines will improve availability of medicines for primary health care and ensure continual access to treatment for patients with chronic conditions.

5.5.3 Healthier biodiversity and ecosystems

The integration of indigenous plants into the agricultural production system will result in a more balanced and harmonious agro-ecosystem. The focus will be on multi-species cropping systems, grown within a broad framework of regenerative agriculture that conserves and nourishes soil, protects indigenous woodland, supports native biodiversity and enables the long term provision of critical ecosystem services. Included amongst these ecosystem services will be catchment protection, pollination, carbon sequestration, water purification, flood protection, pest and disease control and nutrient cycling.

5.5.4 Reduced emissions and improved carbon sequestration

70% of Zimbabwe's green house gas (GHG) emissions come from the production and use of energy. An increased focus on indigenous plants will substantially reduce energy consumption, with concomitant reductions in GHG emissions. Indigenous plants require less land preparation, less agro-chemicals (fertiliser manufacture is especially energy-intensive) and less irrigation than other crops. Protecting and managing indigenous vegetation in situ also protects and enhances the carbon sequestration capacity of the land and the soil.

5.5.5 Robust economy

Increased use of indigenous plants for agriculture will ultimately create a stronger and more robust Zimbabwean economy. A diversification of the crop base will enable farmers to move beyond the current commodity dependence and allow them to focus on their own comparative advantages. Their production will be more resilient to shocks and better able to adapt to changing climatic conditions. New jobs will be created around value addition and new biotechnologies will advance the Zimbabwean knowledge economy. There will be a reduced dependence on fossil fuels and the associated foreign exchange requirements. Healthier ecosystems will translate into more reliable and effective water and waste management. Zimbabwe's international standing will be enhanced by its green credentials, and this will result in greater investment and tourism inflows into the country.

5.5.6 Improved food sovereignty

The move towards indigenous plants reduces the degree of control currently held by large corporations over smallholder farmers. This control is manifested through dependence on expensive inputs linked to low output prices, tied together in contract schemes that are often exploitative and inherently one-sided. Indigenous plants require less in the way of inputs and are often marketed through alternative channels to the conventional large-scale agribusiness operators, significantly reducing the influence of the corporate players and empowering smallholder farmers by giving them greater autonomy in their agricultural decision-making.

Section 6: Conclusions and Recommendations

Zimbabwe's agricultural production system is in the process of renewal and transformation. After a series of shocks induced by poor economic performance, accelerating climate change and a global pandemic, the time has clearly come to move on from "business as usual" and embrace the future. As an exceptionally resource-rich and biodiverse country, it makes strategic sense to the harness the capabilities of these natural and biological resources towards economic growth and sustainability. One of the most underutilised yet high potential categories of biological resource available to Zimbabwe is its wealth of indigenous plants and associated traditional knowledge.

There are nearly 6,000 plant species in Zimbabwe. At least 900 of these (15%) have been used traditionally as foods or medicines, and yet our current agricultural system makes use of only a handful. Instead, we have focused our production efforts on crops that originate elsewhere in the world, making us vulnerable to the vagaries of international commodity prices and unpredictable rainfall. Changing this focus represents a quick and easy win for Zimbabwean farmers and sets the foundations for sustained economic growth going forward.

Concurrent with the need to transform Zimbabwe's agricultural system, a global shift in economic thinking has occurred. Dubbed the "Great Reset" by the World Economic Forum in 2020, this shift recognises the urgent need to reduce our dependency on fossil fuels, meet global emissions targets, adapt to changing climate conditions and create a "greener, smarter, fairer world in the future".

As a bridging mechanism to unite these two different strands, the emergent notion of the bioeconomy is an approach that speaks directly to Zimbabwe's strengths. With its breadth of biological resources and depth of traditional knowledge around their sustainable use, Zimbabwe is exceptionally well-positioned to transition quickly and effectively into a flourishing bioeconomy

This report presents 25 indigenous plant species that have the potential to be adopted at a significant scale in Zimbabwe as smallholder crops. These plants have been selected not only for their ability to generate better and more environmentally sustainable financial returns for smallholders (especially those living in dryland regions) but also for their potential to advance the discourse towards a national bioeconomy strategy for Zimbabwe.
As a follow-up to this study, it is therefore recommended that:

i. A national workshop is convened to discuss the potential role of indigenous plants in a Zimbabwe's agricultural transformation process and develop a broad strategy for the integration of indigenous plants into the production system.
ii. Following on from this workshop, a multi-stakeholder Indigenous Plant Action Team be convened under the leadership of the Ministry of Agriculture to drive the implementation of this strategy.
iii. Separately a team be established to develop a first draft National Bioeconomy Strategy for Zimbabwe for further consultation and eventual adoption.

Annex 1 FAO MA&D Species Selection Matrix

CRITERIA MARKETING	SCALE	SCORE	EXPLANATION	QUALIFIERS
Extent and quality of existing market information	Sufficient/reliable	2	There is sufficient market information to predict demand accurately	Who can provide what kind of (additional) market information?
	Inadequate/uncertain	1	Current market information only allows for demand to be estimated approximately	
	Non-existent/unreliable	0	There is insufficient market information to predict demand	
Actual and projected market demand	High	2	Market demand for this product is known to be high	
	Moderate	1	Market demand for this product is currently moderate, but has the potential to increase	
	Low	0	Market demand for this product is currently small, and it is not certain whether it will increase	
Scale of production	Large	2	Production is well organised and sufficient to be commercially interesting	If organisation of production is the problem can it be tackled? If so, who will be responsible?
	Moderate	1	Production is reasonably organised and could be commercially interesting	
	Small	0	A very limited number of community producers, with low production capacity, is involved. The scale of production is not commercially interesting	
Market readiness of product	Already on market	2	This product is already being sold on the market	
	Under development	1	This product is currently under development, and will be on the market shortly	
	No development underway	0	This product is not on the market, nor has any product development work begun	
Competition (for retaining market niche)	Weak	2	There are few alternative sources of this product, and little likelihood of it being substituted	
	Moderate	1	There are a number of sources for this product, or it could be relatively easily substituted	
	Strong	0	There is, actually or potentially, strong competition for the supply of this product	
Financial viability assessment	Completed, good returns	2	Reliable financial viability assessments have been undertaken, and they predict good returns	If required, who can do an assessment?
	Compl., moderate returns	1	Reliable assessments have been undertaken, predicting moderate returns	
	Not compl., or poor returns	0	No assessments have been undertaken, or reliable assessments have predicted poor returns	
Product standards	Good	2	The community has developed adequate quality standards for the product	If required, who can assist in developing quality standards?
	Moderate	1	The community has developed quality standards for the product, but they need improvement	
	Low	0	The community has not developed quality standards for the product	
Fair trade potential	Good	2	This product is suitable for Fair Trade production, and has a Fair Trade market	If there is Fair Trade potential, who will be responsible for realising this potential?
	Moderate	1	This product is suitable for Fair Trade production, but the market interest is uncertain	
	Low	0	This product cannot be Fairly Traded, or Fair Trade is not relevant to its market	
Organic certification/ Eco-labelling potential	Good	2	This product can be organically produced or eco-labelled, and this has a market	If there is organic/eco-labelling potential, who will be responsible for realising this potential?
	Moderate	1	This product can be organically produced or eco-labelled, but the market interest is uncertain	
	Low	0	This product cannot be organically produced or eco-labelled, or this is not relevant to its market	
SUB TOTAL				

CRITERIA ECOLOGICAL	SCALE	SCORE	EXPLANATION	QUALIFIERS
Conservation status of raw material species	Abundant	2	The source species for this product is abundant, and is not under any ecological threat	If there is not sufficient information to answer this question, can it be generated? If so, who will be responsible?
	Sufficient	1	This species is found in sufficient quantities to meet demand, but could be at risk in the long term	
	Under threat	0	The source species for this product is already endangered or at risk of local extinction	
Regenerative/ Domestication potential	High	2	The source species for this product regenerates easily, or can easily be produced domestically	If there is not sufficient information to answer this question can it be generated? If so, who will be responsible?
	Moderate	1	This species regenerates well in the wild, but cannot be produced domestically	
	Low	0	This species does not regenerate well in the wild, and cannot be produced domestically	
Impact of harvesting on survival of the species	Positive	2	The harvesting of the source species for this product has a positive impact on this and other species	If there is not sufficient information to answer this question can it be generated? If so, who will be responsible?
	Neutral	1	The harvesting of the source species for this product has no impact on this and other species	
	Negative	0	The harvesting of the source species for this product has a negative impact on this and other species	
Existence of a natural resource management system	Exists, and in use	2	The harvesting of the source species for this product is part of a natural resource management system	If required, who can provide assistance to improve the natural resource management system?
	Exists, but improvement is required	1	The harvesting of the source species for this product is part of a natural resource management system. The system needs substantial improvement.	
	Does not exist	0	The harvesting of the source species for this product is not part of a natural resource management system	
Availability of a suitable environmental certification mechanism	Exists, and in use	2	A suitable environmental certification system is available for the product, and it is already in use	If required, who can provide assistance to organise environmental certification?
	Exists, but not in use	1	A suitable environmental certification system is available, but it has not yet been used	
	Does not exist	0	There is no suitable environmental certification system for this product	
Potential for organic production	Exists, and in use	2	The source species for this product can be, and already is, organically produced	If required, who can provide assistance to organise organic production?
	Exists, but not in use	1	This species can be organically produced, although currently it is not	
	Does not exist	0	This species cannot be organically produced	
Potential for mono-cultural production	Does not exist	2	The source species for this product cannot be mono-culturally produced	Assumption of this criterion is that mono-culture has a negative effect on local biodiversity (viz impact on other species)
	Exists, but not in use	1	This species could be mono-culturally produced, but currently is not	
	Exists, and in use	0	This species can be, and already is, mono-culturally produced	
SUBTOTAL				

CRITERIA SOCIO-ECONOMICAL	SCALE	SCORE	EXPLANATION	QUALIFIERS
Suitability for raw material production by community-based producers	High Moderate Low	2 1 0	The raw materials required for this product are highly suited to C-B production These raw materials are moderately suited to C-B production, and difficulties may be experienced These raw materials are more suited to private sector production	Can difficulties be tackled and if so who will take the responsibility?
Experience with products	High Moderate Low	2 1 0	C-B producers have considerable previous experience of producing and selling these raw materials C-B producers have some previous experience of producing and selling these raw materials C-B producers have no previous experience of producing and selling these raw materials	Are there experiences of other CB producers that can be used? Who will take up the responsibility to transfer knowledge and give training?
Opportunities for value-adding by community-based producers	High Moderate Low	2 1 0	There are readily accessible opportunities for C-B producers to add value to the raw materials There are some opportunities for local value-adding, although they may be hard to access There are few, if any, opportunities for C-B producers to add value to the raw materials	If required, who will assist in accessing the opportunities for value adding.
Employment creation potential	High Moderate Low	2 1 0	There are ample opportunities for creating meaningful additional employment as a result of this There are a few opportunities for creating meaningful additional employment as a result of this There are no opportunities for creating meaningful additional employment as a result of this	
Additional indirect benefits to communities as a result of production	High Moderate Low	2 1 0	There are obvious spin-off benefits to rural communities from producing these raw materials There are a few, relatively insignificant, spin-off benefits from producing these raw materials There are no obvious spin-off benefits to rural communities from producing these raw materials	
Gender impact	(Mainly) Women Men & women (Mainly) Men	2 1 0	Profits from the production of these raw materials will accrue mainly to women Profits from the production of these raw materials will accrue equally to women and men Profits from the production of these raw materials will accrue mainly to men	Are there opportunities to change the pattern of profit distribution? Who will be responsible?
SUB TOTAL				

CRITERIA TECHNOLOGICAL	SCALE	SCORE	EXPLANATION	QUALIFIERS
Processing technology requirements	Low	2	The technology required for processing these raw materials is simple and locally available	If technology is not accessible can it be made accessible? Who will be responsible?
	Moderate	1	The technological requirements are complex, or are not readily available locally	
	High	0	The technology required for processing is completely inaccessible to C-B producers	
Quality control requirements	Low	2	The quality standards for these raw materials will be relatively easy for C-B producers to meet	If required, who can give training in order that producers can meet quality standards?
	Moderate	1	The quality standards are attainable by C-B producers, but will need to be carefully monitored	
	High	0	The quality standards for these raw materials are high, and will be difficult or impossible for C-B producers to meet	
Infrastructure status	High	2	The existing local infrastructure is appropriate for the needs of producing and/or processing these raw materials	If required, who will be responsible to ensure additional infrastructure development?
	Moderate	1	Some additional infrastructure development would be required for producing and/or processing these raw materials	
	Low	0	The additional infrastructure required to allow producing and/or processing these raw materials would be prohibitively costly	
Human resources / skills (expertise)	Low	2	The existing skills-base within communities is sufficient for successful production of these raw materials	If required, who will be responsible to ensure additional capacity building?
	Moderate	1	Some additional capacity-building would be required amongst communities for successful production	
	High	0	Considerable additional capacity-building would be required for successful production	
Human resource / number	High	2	There is an ample supply of human resources within the community for successful production of these raw materials	Can the limited supply of human resources be solved? How?
	Moderate	1	There is a moderate supply of human resources, but periodic labour shortages may affect production	
	Limited	0	There is only a limited supply of human resources, and production will be seriously constrained by shortages	
Technical support skills	Available	2	The technical skills required to support C-B production of the raw materials are readily available locally	If required, who will be responsible to ensure technical support?
	Moderate	1	If effective technical support is to be given, some technical skills will have to be imported from elsewhere	
	Limited	0	Few, if any, technical skills exist locally to support production, and most will have to be imported from elsewhere	
SUBTOTAL				
GRAND TOTAL				
RANK				

Annex 2 Long List

	Latin	English	Shona	Ndebele	Uses
1	*Adansonia digitata*	Baobab	Muuyu	Umkhomo	Food, Beverage, Cosmetic (skincare)
2	*Aloe excelsa*	Zimbabwe tree aloe	Chikohwa	Imangani	Cosmetics (Skincare)
3	*Amaranthus hybridus*	Pigweed, Amaranth	Mowa	Imbuya	Food, Cosmetic (skincare)
4	*Annona senegalensis*	Wild custard apple	Muroro	Ubububese	Food
5	*Artemeisia afra*	African wormwood			Medicinal (Cough, cold, flu, malaria, headache)
6	*Azanza garckeana*	Snot apple, chewing gum tree	Mutohwe	Uxakuxaku	Food, Medicinal (cough, chestpain, nausea, libido)
7	*Balanites aegyptiaca*	Simple-thorned toch-wood	Muvambangoma, Nyahoko		Food, Cosmetics
8	*Berchemia discolor*	Bird plum	Munyii	Umnyiyi	Food, Medicinal (wound treatment)
9	*Bobgunnisa madagas-cariesnis*	Snakebean	Mucherekese		Medicinal (Malaria, bilharzia), Insect anti-feedant
10	*Bulbine latifolia (natal-ensis)*	Broad-leaved Bulbine			Cosmetics (Skincare)
11	*Calodendrum capense*	Cape chestnut, Yangu		Umbaba	Cosmetic (oil used in skincare)
12	*Cassia abbreviata*	Long-tail cassia, sjambok pod	Muremberembe, Muvheneka	Isihaqa	Medicinal (diarrhoea, malaria, anti-bacterial, toothache, eyewash)
13	*Catharanthus roseus*	Madagascar periwinkle, rosy periwinkle	Chirindamatongo		Medicinal (diabetes, cancer)
14	*Cenchrus americanus*	Pearl millet	Mhunga	Inyawuthi	Food, beverage
15	*Centella asiatica*	Gotu kola			Medicinal (Antibacterial, antifungal, antiin-flammation, skin conditions)
16	*Citrullus lanatus*	Kalahari melon	Muvembe, Majoda, Munwiwa		Cosmetics (Skincare)
17	*Cleome gynandra*	Spider plant	Bangava, Nyevhe, Rud-he, Runi, Tsuna	Ulude	Food, Medicinal (eyesight)
18	*Coffea racemosa*	Inhambane coffee, Mozambique coffee			Food
19	*Corchorus olitorius*	Indian jute	Derere regusha, Guse, Gusha, Gwisha, Nyenje	Idelele, Igogola	Food, Beverage
20	*Croton gratissimus*	Lavender croton	Gunukira, Mubangwa, Mufandemengwe, Mufarata		Cosmetics (Skincare)
21	*Cucumus metuliferus*	Jelly melon, Kiwano, Horned cucumber	Magaka, Magagachika, Mugamganam, Mugu-musambwa, Mushonja, Mutete	Umhlagahlaga	Food
22	*Cyperus esculentus*	Tiger nut, yellow nutsedge	Pfende	Inqodi	Food
23	*Dioscorea bulbifera*	Air potato, bitter yam	Idiya		Food, medicine
24	*Diospyros mespiliformis*	Jackal-berry, African ebony	Mushenje		Food
25	*Dovyalis caffra*	Kei apple	Munhungura, Musvis-virondo	Umqokolo	Food
26	*Elephantorrhiza ele-phantina*	Elephant-rootq	Chizezepasi	Intolwane encinyane	Medicinal (antibacterial, antiplasmodial, dermatological, gastro-intestinal)
27	*Eleusine coracana*	Finger millet	Rapoko	Majolothi	Food
28	*Erythrina abyssinca*	Lucky bean tree, red hot poker tree	Mutiti, Munhimbiti, Mutete	Umgqogqogqo	Medicinal (antimicrobial, antiplasmodial, dysentery)
29	*Fadogia ancylantha*	Makoni tea	Makoni		Beverage
30	*Faidherbia albida*	Ana tree, apple ring	Musangu, Musanga, Musenga	Umpumbu	Medicinal (ocular)
31	*Ficus sur*	Cape fig	Mukuyu		Food
32	*Ficus sycomorus*	Sycomore fig	Mukuyu, Muonde	Umkhiwa	Edible fruit, Medicinal (diarrhoea, anthel-mintic, coughs)
33	*Flacourtia indica*	Governor's plum, Bato-ka plum	Munhunguru, Mududwe, Mutombototo, Mutudza, Mutunguru		Food
34	*Garcinia livinstonei*	African mangosteen	Himbi, Munhinzwa, Mutunduru	Umthunuduluka	Food
35	*Gloriosa superba*	Flame lily	Kajongwe	Amakukhulume	Medicinal (cancer, hemarrhoids, intestinal worms)

36	*Harpagophytum zeyherii*	Devil's claw			Medicinal (rheumatism, arthiritis, anti-inflammation)
37	*Helichrysum nudifolium*	Hottentot's tea	Nyamuchena		Medicinal (Wound dressing, antibacterial, cough, cold, fever)
38	*Heteropyxis natalensis*	Lavender tree			Medicinal (nosebleed, intestinal worms), Cosmetic (Essential oil)
39	*Hyphaenae petersiana*	Ilala palm	Murara, Muzira	Ilala	Beverage
40	*Hypoxis hemerocallidea*	African potato	Nhindiri		Medicinal (rheumatism, arthiritis, anti-inflammation)
41	*Kigelia africana*	Sausage tree	Mubvee, Mubveve, Musonya, Muvhumati	Umvebe	Medicinal (cancer, skin ailments), Cosmetic (skincare), Beverage (brewing bittering)
42	*Lagenaria siceraria*	Calabash, bottle gourd	Mapodze	Amakhomane	Food
43	*Lannea edulis*	Wild grape	Mutsambatsi	Utsombole, Intakubom-vu	Food
44	*Lippia javanica*	Fever tea	Zumbani, Kachigwere, Mumara, Mushani mukuru, Musumba	Umsuzwane	Medicinal (coughs, colds, bronchial, malaria), Cosmetic (skincare), Beverage (herbal tea)
45	*Mimusops zeyheri*	Red milkwood	Muchechete, Muchirinje, Mukaurura, Mutunzi, Svanzwa	Umbumbulu	Food
46	*Myrothamnus flabellifolia*	Resurrection	Mufandichimuka		Medicinal (bronchial), Cosmetic (skincare), Beverage (herbal tea)
47	*Ocimum africanum*	Wild basil			Food
48	*Olea europaea subsp cuspidata*	Wild olive, African olive	Mupfungo	Umguma, Umnquma	Medicinal (Hypertension)
49	*Oryza glaberrima*	African rice	Mupunga	Ingqoloyi	Food
50	*Parinari curatellifolia*	Mobola plum	Muhacha, Muchakata, Mubuni, Muisha	Umkuna	Food
51	*Peltophorum africanum*	Weeping wattle	Muzeze, Dzedze, Mudji-za, Musambanyoka,	Umkhala, Umsehla	Medicinal (sore throat, cough)
52	*Pennisetum glaucum*	Pearl millet	Mhunga	Inyawuti	Food
53	*Piliostigma thoningii*	Monkey bread, camel foot	Musekesa, Mubaba, Mutukutu, Muhuku, Musakasa	Ihabahaba	Medicinal (stomach aches, coughs, snake-bites)
54	*Prunus africana*	Pygeum, African almond	Muchambati		Medicinal (Antibacterial, antifungal, antiin-flammation, skin conditions)
55	*Rauvolfia caffra*	Quinine tree	Mudzurungu, Mukashu, Mukamamahsani, Mukaurura, Musing-wiswi, Mutowamakaka, Muzungurwi		Medicinal (fever, malaria)
56	*Salvadora persica*	Mustard tree, tooth-brush tree			Medicinal (antibacterial, antiplaque)
57	*Sansevieria hyacinthoides*	African bowstring hemp			Medicinal (hemarrhoids, anti-inflammatory)
58	*Schinziophyton rautanenii*	Manketti, Mongongo	Mungongoma	Umgoma	Food
59	*Sclerocarya birrea*	Marula	Mupfura, Mutsomo, Mukwakwa, Mufuna, Mushomo	Umganu	Food
60	*Sorghum bicolor*	Sorghum	Mapfunde	Amabele	Food
61	*Strophanthus kombe*	Zambezi tail flower			Medicinal (cardio stimulant)
62	*Strychnos spinosa*	Monkey orange	Mutamba, Mutamba mun'ono	Umhahli, Umngono	Food
63	*Syzigium cordatum*	Water berry	Mukute	Umdoni	
64	*Tarconanthus camphor-atus*	Camphor bush, Wild sage bush			Cosmetics (Skincare)
65	*Terminalia sericea*	Silver leaf terminalia	Mususu, Mangwe, Mukono, Mutabvu	Umangwe	Cosmetics (Skincare)
66	*Trichilia emetica*	Natal mahogany	Muchichiri, Mutsikiri		Cosmetics (Skincare)
67	*Tylosema fassoglense*	Marama bean	Mutukutupasi, Gwang-wandiza, Mubopo, Mudamura,	Inqwalla, Umdabule	Food
68	*Uapaca kirkiana*	Mahobohobo	Muzhanje, Mahobohobo, Mushuku, Mutongoro	Umhobohobo	Food
69	*Vachellia erioloba*	Camel thorn		Umwholo	Medicine (ears, headaches, STDs)
70	*Vachellia karroo*	Sweet thorn	Muhunga, Mubayom-hondoro, Munenje, Muzunga	Isinga	Food

71	*Vangueria infausta*	Wild medlar	Munzviro, Munjiro, Munzvirwa	Umviyo, Umtohfu	Food
72	*Vernonia amygdalina*	Bitter tea vernonia	Dembezeko, Musika-vakadzi, Myareru	Inyathelo	Medicinal (antiplasmodial, diarrhoea)
73	*Vigna subterranea*	Nyimo bean, bambara nut	Nyimo	Imdlubu	Food
74	*Vigna unguiculata*	Cow pea	Nyemba	Indumba	Food
75	*Vitex payos*	Chocolate berry	Mutsubvu, Mudyagava, Muhubva, Muhubvu, Mukubvu,	Umtshwankela	Food
76	*Warburgia salutaris*	Pepper bark	Muranga		Medicinal (pulmonary, malaria)
77	*Withania somnifera*	Ashawaganda, poison goose-berry			Medicinal (Antibacterial, antifungal, antiin-flammation, skin conditions)
78	*Ximenia caffra*	Ximenia	Munhengeni, Mutengeni, Mutsvansva,	Umthunduluka	Cosmetics (Skincare)
79	*Ziziphus mauritiana*	Jujube	Musau		Food, Beverage

Annex 3 Short List

					Eco-Regions of Zimbabwe								
	Latin	**English**	**Shona**	**Ndebele**	Zambezi	Kalahari	Central	Save- Limpopo	**Uses**	**Plant Type (Herb, Shrub, Tree, Climber, Creeper)**	**Distribution**	**Degree of drought tolerance (<600 mm annual rainfall)**	**Suitability for cultivation**
1	Adansonia digitata	Baobab	Muuyu	Umkhomo	X	X	X	X	Food, Beverage, Cosmetic (skincare)	Tree	Throughout Sub-Saharan Africa	High	Not easily cultivated
2	Aloe excelsa	Zimbabwe tree aloe	Chikohwa	Imangani	X	X	X	X	Cosmetics (Skincare)	Tree	Zimbabwe, Mozambique, South Africa	High	Already cultivated
3	Artemesia afra	African wormwood			X		X	X	Medicinal (Cough, cold, flu, malaria, headache)	Shrub	Eastern and Southern Africa	Low	Currently wild harvested with potential for cultivation
4	Cenchrus americanus	Pearl millet	Mhunga	Inyawuthi	X	X	X	X	Food, Beverage	Herb	Worldwide in the tropics	High	Already cultivated
5	Citrullus lanatus	Kalahari melon	Muvembe, Majoda, Munwiwa		X	X	X	X	Cosmetics (Skincare)	Creeper	Worldwide in the tropics	High	Already cultivated
6	Cleome gynandra	Spider plant	Nyevhe	Ulude	X	X	X	X	Food	Herb	Worldwide in the tropics	High	Already cultivated
7	Cucumis metuliferus	Jelly melon, Kiwano, Horned cucumber	Magaka, Magagachika, Mugamganam, Mugumusambwa, Mushonja, Mutete	Umhlagahlaga	X	X	X	X	Food	Herb	Worldwide in the tropics	High	Already cultivated
8	Cyperus esculentus	Tiger nuts, Yellow nutsedge	Pfende	Inqodi	X	X	X	X	Food	Herb	Worldwide	High	Currently wild harvested with potential for cultivation
9	Eleusine coracana	Finger millet, Rapoko	Zviyo, Rukweza	Uphoko	X	X	X	X	Food, Beverage	Herb	Worldwide in the tropics	High	Already cultivated
10	Fadogia ancylantha	Makoni tea	Makoni		X		X	X	Beverage	Shrub	Tropical Africa	High	Currently wild harvested with potential for cultivation
11	Harpagophytum zeyherii	Devil's claw		Inkunzane enkulu		X		X	Medicinal (rheumatism, arthiritis, anti-inflammation)	Herb	Southern Africa	High	Not easily cultivated
12	Hyphaene petersiana/ coriacea	Ilala palm	Murara, Muzira	Ilala	X	X		X	Beverage	Tree	Southern Africa	High	Not easily cultivated
13	Lippia javanica	Fever tea	Zumbani, Kachigwere, Mumara, Mushani mukuru, Musumba	Umsuzwane	X	X	X	X	Medicinal (coughs, colds, bronchial, malaria), Cosmetic (skincare), Beverage (herbal tea)	Shrub	Southern Africa	High	Already cultivated
14	Myrothamnus flabellifolia	Resurrection	Mufandichimuka		X		X		Medicinal (bronchial), Cosmetic (skincare), Beverage (herbal tea)	Shrub	Southern Africa	High	Not easily cultivated

15	Oryza glaberrima	African rice	Mupunga		X	X	X	X	Food	Herb	Worldwide in the tropics	Low	Already cultivated
16	Parinari curatellifolia	Mobola plum	Muhacha, Muchakata, Mubuni, Muisha	Umkuna	X	X	X	X	Food	Tree	Southern Africa	Low	Not easily cultivated
17	Plectranthus esculentus	Livingstone potato, finger potato	Tsenza	Umbondiwe	X	X	X	X	Food	Herb	Tropical Africa	Low	Already cultivated
18	Schinziophyton rautanenii	Manketti, Mongongo	Mungongoma	Umgoma	X	X	X		Food	Tree	Southern Africa	High	Currently wild harvested with potential for cultivation
19	Sclerocarya birrea	Marula	Mupfura, Mutsomo, Mukwakwa, Mufuna, Mushomo	Umganu	X	X	X	X	Food	Tree	Eastern and Southern Africa	High	Currently wild harvested with potential for cultivation
20	Trichilia emetica	Natal mahogany	Muchichiri, Mutsikiri		X	X	X	X	Cosmetics (Skincare)	Tree	Southern Africa	High	Currently wild harvested with potential for cultivation
21	Uapaca kirkiana	Mahobohobo	Muzhanje, Mahobohobo, Mushuku, Mutongoro	Umhobohobo	X		X	X	Food	Tree	Southern Africa	Low	Not easily cultivated
22	Vigna subterranea	Nyimo bean, bambara nut	Nyimo	Imdlubu	X	X	X	X	Food	Climber	Tropical Africa	High	Already cultivated
23	Vigna unguiculata	Cow pea	Nyemba	Indumba	X	X	X	X	Food	Climber	Worldwide in the tropics	High	Already cultivated
24	Ximenia caffra	Ximenia	Munhengeni, Mutengeni, Mutsvansva,	Umthunduluka	X	X	X	X	Cosmetics (Skincare)	Tree	Eastern and Southern Africa	High	Currently wild harvested with potential for cultivation
25	Ziziphus mauritiana	Jujube, Masau	Masau		X				Food, Beverage	Tree	Eastern and Southern Africa, India	High	Currently wild harvested with potential for cultivation

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