Journal of Ethnopharmacology 119 (2008) 342–355

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jethpharm

Review

A broad review of commercially important southern African medicinal plants

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ARTICLE INFO

Article history:
Received 8 May 2008
Received in revised form 14 May 2008
Accepted 16 May 2008
Available online 3 June 2008

Keywords:
Biosystematics
Chemical variation
Commercial development
Medicinal plants
Southern Africa
Taxonomy

ABSTRACT

Aims of the study: Commercially important indigenous medicinal plants of southern Africa are reviewed in the context of fundamental knowledge about their ethnobotany, phylogeny, genetics, taxonomy, biochemistry, chemical variation, reproductive biology and horticulture. The aim is to explore the rapidly increasing number of scientific publications and to investigate the need for further research.
Materials and methods: The Scopus (Elsevier) reference system was used to investigate trends in the number of scientific publications and patents in 38 medicinal plant species. Fifteen species of special commercial interest were chosen for more detailed reviews: *Agathosma betulina, Aloe ferox, Artemisia afra, Aspalathus linearis, Cyclopia genistoides, Harpagophytum procumbens, Hoodia gordonii, Hypoxis hemerocallidea, Lippia javanica, Mesembryanthemum tortuosum, Pelargonium sidoides, Siphonochilus aethiopicus, Sutherlandia frutescens, Warburgia salutaris* and *Xysmalobium undulatum*.
Results: In recent years there has been an upsurge in research and development of new medicinal products and new medicinal crops, as is shown by a rapid increase in the number of scientific publications and patents. Despite the fact that an estimated 10% of the plant species of the world is found in southern Africa, only a few have been fully commercialized and basic scientific information is often not available.
Conclusions: The limited available information indicates that some of the plants display remarkable regional variation in morphological, genetic and chemical characters that should be more thoroughly investigated. Basic biological information is needed to guide the rapidly accelerating commercialization process, especially the selection of superior clones, the development of new cultivars and the standardization of raw materials.

Contents

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doi:10.1016/j.jep.2008.05.029

1. Introduction

Africa, and especially southern Africa, has a rich diversity of plants. Recent statistics show that about 25% of the total number of higher plants in the world is found in Africa south of the Sahara. According to the "African Plant Checklist and Database Project" (Klopper et al., 2006), a total of 50,136 angiosperm taxa occur in tropical Africa and southern Africa. This figure is based on a recent merging of two major data bases—EPFAT (Enumération des plantes à fleurs d'Afrique) and FSA (Flora of southern Africa). The combined checklist shows a total of 32,424 taxa in tropical Africa and 22,755 taxa in southern Africa. A useful reference book on the medicinal plants of the whole of the African continent (Neuwinger, 2000) lists more than 5400 medicinal plant taxa and over 16,300 medicinal uses. It is generally accepted (e.g. Geldenhuys and Van Wyk, 2002) that natural resources will play a major role in the socio-economic development of the African continent. The angiosperm species count for southern Africa (Germishuizen and Meyer, 2003) is 21,817 and the count for the Cape Floristic Region (Goldblatt and Manning, 2001) is 8888. Van Wyk and Gericke (2000) estimated that about 3000 medicinal plants are regularly used in southern Africa. An annotated checklist of traditional medicinal plants of southern Africa (Arnold et al., 2002) gives a total of 3481 plant taxa, of which 2942 are administered to people only. Basic information about the most widely used species can be found in Van Wyk et al. (1997), Van Wyk and Gericke (2000) and Diederichs (2006). This diversity represents a very valuable resource, not only for commercial development but also for basic scientific study.

This paper is aimed at reviewing southern African medicinal plants that are currently of particular interest in new product development. Basic researches relating to 15 commercially highly relevant species in South Africa are briefly reviewed. The aim is to show the potential value and application of fundamental knowledge, to explore the rapidly accelerating numbers of scientific publications and to highlight the need for further biosystematic research on southern African plants.

2. Commercialized indigenous plant species

Of the estimated 3000 medicinal plant species that are regularly used in traditional medicine in South Africa, only about 38 indigenous species have been commercialized to some extent (i.e. they are available as processed materials in modern packaging and in various dosage forms as teas, tinctures, tablets, capsules or ointments). Several others are also produced for multi-million Rand informal markets (Cunningham, 1988; Mander, 1998; Williams et al., 2000). A useful review of various aspects of the commercialization process in South Africa is given by Diederichs (2006). The major commercialized species are listed in Table 1, together with basic ethnobotanical information and some key references. The list includes indigenous species that are widely distributed in Africa and that have been extensively commercialized in other parts of Africa and/or in other parts of the world (e.g. *Adansonia digitata*, *Centella asiatica*, *Kigelia africana*, *Prunus africana* and *Trichilia emetica*). Also included are two famous and popular herbs of Ayurvedic medicine that have hitherto been of limited commercial interest in South Africa (*Centella asiatica* and *Withania somnifera*). Wild-harvested material of *Merwilla plumbea* (Lindl.) Speta (syn. *Scilla natalensis* Planch.), *Bowiea volubilis* Harv. ex Hook.f. and several other important medicinal plant species is traded in large volumes on local markets but have as yet only been formally commercialized to a limited extent. Several of the plants listed in Table 1 are endemic to southern Africa and some of them are treated in detailed reviews in this volume.

In order to gain some insight into the scientific and/or commercial interest in South African medicinal plants, a literature search was conducted with the well-known Scopus literature reference system maintained by Elsevier. Using the scientific names of the species and the "quick search" option, varying numbers of "hits" were obtained for those species listed in Table 1. The searches were carefully executed to include main synonyms and other commercial species of the same genus where relevant (e.g. *Cyclopia*). The results are summarized in Table 2, which outlines the number of scientific publications and the number of citation in patents in recent years. The general trend is one of an increasing number of papers and citations since 1995, although this is not true for all the species. The popularity of *Centella asiatica* and *Withania somnifera* in Ayurvedic medicine is reflected in the large number of citations and publications over many years. Relatively large numbers are also seen for those species that are well established in tropical Africa as important medicinal plants (e.g. *Adansonia digitata*, *Kigelia africana* and *Prunus africana*). These species have been of limited commercial interest in South Africa despite their popularity elsewhere.

Table 2 reveals a rapid increase in the number of publications and patent citations for several indigenous species that were scientifically practically unknown and unstudied prior to 1995. Raw material of some species has only become available in commercial quantities in recent years, so that the number of ethnopharmacological studies has sharply increased since 1995. This trend was discussed by Light et al. (2005, and references cited therein) and is also reflected in review papers in this volume. In several cases, the number of scientific papers published since 2006 (i.e., a period of just over 2 years) already exceed those published in the preceding 5-year periods of 1995–2000 and 2001–2005. Notable examples are *Cyclopia genistoides*, *Euclea natalensis*, *Hoodia gordonii*, *Hypoxis hemerocallidea*, *Pelargonium sidoides* and *Sutherlandia frutescens*. Rapid recent increases in the number of patent citations are also evident, especially for *Adansonia*, *Aspalathus*, *Cyclopia*, *Harpagophytum*, *Hoodia*, *Mesembryanthemum*, *Pelargonium* and *Sutherlandia*. Well-known commercialized species such as *Harpagophytum procumbens* and *Aloe ferox* has been the subject of scientific investigation over many years. The decreasing trend in *Mesembryanthemum tortuosum* is due an early interest in the unique alkaloids of these plants and a rather slow pace of commercialization. Recent research and development activity is also reflected in the data for some well-established commercial species, including *Aspalathus linearis* and *Xysmalobium undulatum* (both of which were first commercialized more than 100 years ago).

3. Biosystematic and chemotaxonomic studies

A summary of published information on a selection of 15 commercially relevant medicinal plants of South Africa (see Fig. 1 and Tables 1 and 2) is given below. General information about these plants can be obtained from Watt and Breyer-Brandwijk (1962), Hutchings et al. (1996), Van Wyk et al. (1997), Van Wyk and Gericke (2000) and Van Wyk and Wink (2004). Each of the species is briefly discussed, with emphasis on what is known about their ethnob-

Table 1
Indigenous South African medicinal plants of current interest in product development (locally and elsewhere)

Species	Main traditional uses in South Africa (traditional uses elsewhere or modern uses, if different, in brackets)	Key references and monographs
Adansonia digitata L.	Fever, diarrhoea, haemoptysis, hiccup remedy (urinary disorders)	[1], [2], [3], [4]
Agathosma betulina (P.J.Bergius) Pillans	Stomach complaints, bitter tonic, wound-healing, traditional antiseptic and cosmetic (diuretic, urinary tract disinfectant, flavourant)	[1], [2], [3], [4], [5]
Aloe ferox Mill.	Bitters: laxative, bitter tonic; gel: wound-healing (health drink, cosmetic)	[1], [2], [3], [4], [5], [6]
Artemisia afra Jacq. ex Willd.	Colds and influenza, stomach ailments, bitter tonic, analgesic, anthelmintic, traditional inhalant for a blocked nose	[1], [2], [3], [4], [5]
Aspalathus linearis (Burm.f.) R.Dahlgren	Antispasmodic, traditional milk substitute for infants prone to colic, health drink	[1], [2], [3], [4], [5], [6]
Athrixia phylicoides DC.	Health tea, aphrodisiac	[4], [6]
Bulbine frutescens (L.) Willd.	Wounds, burns, rashes, itches	[1], [2], [3], [4]
Carpobrotus edulis (L.) L.Bolus	Gargle for mouth and throat infections, dysentery, digestive ailments, tuberculosis, diuretic, styptic; topical application against eczema, wounds, burns	[1], [2], [3], [4]
Centella asiatica (L.) Urb.	General tonic, leprosy, wounds and cancer (venotonic, prevention of scar tissue formation, adaptogen, acne, allergies)	[1], [2], [3], [4], [5]
Cyclopia genistoides (L.) R.Br.	Health drink, digestive, stomachic (antioxidant)	[1], [2], [3], [4], [5]
Dodonaea viscosa (Jacq.) var. *angustifolia* (L.f.) Benth,	Fever, colds, influenza, stomach ailments, measles, gargle for sore throat and oral thrush, pneumonia, tuberculosis, topical anti-pruritic	[1], [2], [3], [4]
Elytropappus rhinocerotus (L.f.) Less.	Indigestion, dyspepsia, ulcers, stomach cancer, fumigant against influenza; appetite stimulant, bitter tonic	[1], [2], [3], [4]
Eriocephalus africanus L.	Diaphoretic, diuretic, stomach ache	[1], [2], [3], [4]
Euclea natalensis A.DC.	Bronchitis, chest ailments, pleurisy, asthma, urinary tract infections, toothache, headache, toothbrush sticks	[1], [2], [4]
Eucomis autumnalis (Mill.) Chit.	Urinary diseases, stomach ache, diarrhoea, enema for low back pain and healing of fractures	[1], [2], [3], [4]
Gunnera perpensa L.	Antenatal and postnatal medicine, uterotonic, stomach ailments, menstrual pain, stomach bleeding, rheumatic fever, topical application for wounds and psoriasis	[1], [2], [3], [4]
Harpagophytum procumbens (Burch.) DC. ex Meisn.	Antirheumatic, anti-inflammatory, weakly analgesic, bitter tonic, wound-healing	[1], [2], [3], [4], [5]
Heteropyxis natalensis Harv.	Leaves for colds, weaning; roots for nose bleeds and bleeding gums, menorrhagia	[1], [2], [3], [4]
Hoodia gordonii (Masson) Sweet ex Decne	Appetite and thirst supressant	[1], [2], [3], [4], [5], [6]
Hypoxis hemerocallidea Fisch. & Avé-Lall.	Emetic to treat bladder disorders, dizziness and insanity, traditional tonic, prostate hyperplasia	[1], [2], [3], [4], [5], [6]
Kigelia africana (Lam.) Benth.	Powdered fruit applied to treat sores, wounds and rheumatism; bark used to treat dysentery and stomach ailments (skin care, cosmetic)	[1], [2], [3], [4], [5]
Leonotis leonurus (L.) R.Br.	Coughs, colds, influenza, asthma, bronchitis, high blood pressure, headache, viral hepatitis; topcally applied to treat skin disorders and cramps	[1], [2], [3], [4], [6]
Lippia javanica (Burm.f.) Spreng.	Fever, cough, colds, bronchitis, influenza, measles, rashes, malaria, stomach ailments, headache (insect repellent)	[1], [2], [3], [4], [5]
Lobostemon fruticosus (L.) H.Buek.	Wound-healing, traditional multi-purpose plaster, ringworm	[1], [2], [3], [4]
Mesembryanthemum tortuosum L. (syn. *Sceletium tortuosum*)	Hypnotic, sedative	[1], [4], [5], [6]
Ocotea bullata (Burch.) Baill.	Headache, diarrhoea; emetic for emotional and nervous disorders	[1], [2], [3], [4]
Olea europaea L. subsp. *africana* (Mill.) P.S.Green	Anti-hypertensive, diuretic, tonic, diarrhoea, sore throat	[1], [2], [3], [4]
Pelargonium sidoides DC.	Tuberculosis, diarrhoea (bronchitis, infections of the upper respiratory tract)	[1], [2], [3], [4], [5], [6]
Prunus africana (Hook.f.) Kalkman	Chest pain, benign prostate hyperplasia	[1], [2], [3], [4], [5]
Sclerocarya birrea (A.Rich.) Hochst.	Stomach ailments, diarrhoea, dysentery, fever, malaria, general tonic (diabetes)	[1], [2], [3], [4]
Securidaca longepedunculata Fresen	Cough, chest complaints, rheumatism, tootache, headache, wounds and sores, rheumatism (traditional panacea, general tonic, antirheumatic, antitussive)	[1], [2], [3], [4], [5]
Siphonochilus aethiopicus (Schweinf.) B.L.Burtt	Colds, cough, influenza, hysteria, pain, asthma, dysmenorrhoea, anti-inflammatory, bronchodilatory, traditional antimalarial	[1], [2], [3], [4], [5], [6]
Sutherlandia frutescens (L.) R.Br.	Adaptogenic tonic, traditional general tonic, traditional cancer tonic, skin disorders, eye disorders, diabetes, numerous other ailments	[1], [2], [3], [4], [5], [6]
Trichilia emetica Vahl	Stomach ailments, dysentry, kidney ailments, indigestion, fever, parasites; poultices for bruises and eczema; seed oil for rheumatism	[1], [2], [3], [4]
Tulbaghia violacea Harv.	Colds, fever, asthma, tuberculosis	[1], [2], [3], [4]
Warburgia salutaris (Bertol.f.) Chiov.	Coughs, colds, chest ailments, influenza, rheumatism, malaria, venereal diseases, headache, toothache, gastric ulcers (antibiotic, general tonic)	[1], [2], [3], [4], [5]
Withania somnifera (L.) Dunal	Leaves: poultices to treat wounds, sores, abscesses, inflammation, haemorrhoids, rheumatism, syphilis; roots: asthma, tonic (sedative, adaptogenic tonic)	[1], [2], [3], [4]
Xysmalobium undulatum (L.) W.T.Aiton	Diarrhoea, dysentery, stomach cramps, headache, oedema, dysmenorrhoea; topically to treat sores and wounds (anti-diarrhoeal, spasmolytic, wound-healing)	[1], [2], [3], [4], [5]

Names of species treated in this review are shown in bold. General references: [1] = Watt and Breyer-Brandwijk (1962); [2] = Hutchings et al. (1996); [3] = Van Wyk et al. (1997); [4] = Van Wyk and Gericke (2000); [5] = Van Wyk and Wink (2004); [6] = reviews elsewhere in this volume.

Table 2
Number of citations ("hits") in scientific publications and patents of South African medicinal plants of current interest in product development, as obtained from a search using the Scopus (Elsevier) reference system on 25 April 2008

Species	Number of citations in publications						Number of citations in patents					
	<1990	1990–1995	1996–2000	2001–2005	2006–2008	Total	<1990	1990–1995	1996–2000	2001–2005	2006–2008	Total
Adansonia digitata	12	18	25	45	31	131	3	0	6	16	26	51
Agathosma betulina	0	0	2	3	6	11	0	0	1	1	8	11
Aloe ferox	3	9	7	22	14	55	19	12	27	58	51	167
Artemisia afra	1	1	13	17	10	42	0	0	1	1	0	2
Aspalathus linearis	3	9	22	33	22	89	1	16	25	70	93	204
Athrixia phylicoides	0	0	0	1	7	8	0	0	0	1	0	1
Bulbine frutescens	0	1	1	7	2	11	0	0	1	4	1	6
Carpobrotus edulis	4	4	10	19	6	43	0	0	1	2	1	4
Centella asiatica	56	38	77	169	101	439	24	38	184	441	389	1076
Cyclopia genistoide*s*	0	2	6	9	10	27	0	0	1	8	12	21
Dodonaea angustifolia	1	0	3	10	6	20	0	0	0	2	1	3
Elytropappus rhinocerotus	1	0	2	3	5	12	0	0	2	0	0	2
Eriocephalus africanus	0	5	10	9	4	28	0	0	2	6	4	12
Euclea natalensis	2	4	5	6	10	27	0	0	5	62	36	103
Eucomis autumnalis	3	2	2	17	8	32	0	1	2	2	6	11
Gunnera perpensa	0	0	1	8	3	12	0	0	0	0	1	1
Harpagophytum procumbens	41	13	41	119	50	264	2	5	28	59	72	166
Heteropyxis natalensis	0	1	1	1	5	8	0	0	0	0	1	1
Hoodia gordonii	0	0	0	6	17	23	0	0	3	82	180	265
Hypoxis hemerocallidea	7	8	4	15	18	52	11	5	5	38	19	78
Kigelia africana	9	6	9	22	15	61	1	1	5	26	8	41
Leonotis leonurus	4	0	2	8	6	20	0	0	2	4	2	8
Lippia javanica	3	3	4	12	6	20	0	0	1	1	3	5
Lobostemon fruticosum	0	0	8	3	3	14	0	0	1	1	3	5
Mesembryanthemum tortuosum	21	11	13	6	4	55	1	0	4	7	9	21
Ocotea bullata	0	2	7	7	0	16	0	0	0	0	0	0
Olea europaea subsp. africana	4	2	9	16	3	33	0	0	1	3	4	8
Pelargonium sidoides	0	2	7	20	39	68	0	0	2	5	12	19
Prunus africana	5	1	18	32	12	68	8	0	4	33	14	59
Sclerocarya birrea	1	7	11	40	42	101	0	0	2	3	7	12
Securidaca longepedunculata	3	1	5	13	14	36	0	0	0	1	0	1
Siphonochilus aethiopicus	0	0	6	11	1	18	0	0	0	0	1	1
Sutherlandia frutescens	0	0	2	27	12	35	0	0	0	2	9	11
Trichilia emetica	2	0	6	11	7	26	0	0	1	0	2	3
Tulbaghia violacea	2	3	1	8	7	21	0	0	1	0	3	4
Warburgia salutaris	0	0	6	12	6	24	0	0	0	0	0	0
Withania somnifera	56	33	87	195	140	511	0	0	17	98	89	204
Xysmalobium undulatum	0	1	1	6	2	10	0	0	1	2	0	3

The 15 species discussed in this review are shown in bold.

Fig. 1. Southern African medicinal plants of current interest in product and crop development. 1st row (from left to right): *Agathosma betulina*, *Aloe ferox*, *Artemisia afra*, *Aspalathus linearis*; 2nd row: *Cyclopia genistoides*, *C. maculata*, *Harpagophytum procumbens*, *Hoodia gordonii*; 3rd row: *Hypoxis hemerocallidea, Lippia javanica, Mesembryanthemum tortuosum*, *Pelargonium sidoides*; 4th row: *Siphonochilus aethiopicus*, *Sutherlandia frutescens*, *Warburgia salutaris* and *Xysmalobium undulatum*. Photographer: B.-E. van Wyk.

otany, basic biology and especially their biosystematics, including taxonomic, genetic and chemical variation.

3.1. *Agathosma betulina (P.J. Bergius) Pillans (Rutaceae)-round leaf buchu*

Buchu is an important plant in the Khoi-San tradition (Van Wyk and Gericke, 2000) and still enjoys a great reputation as a general health tonic, diuretic and mild urinary antiseptic. The essential oil is a valuable flavour product (similar to *cassis*) and is probably responsible for the antispasmodic, antiseptic and diuretic activities (Wichtl and Bisset, 2000; Lis-Balchin et al., 2001). Isomenthone and diosphenol are the major volatile compounds (Kaiser et al., 1975; Posthumus et al., 1996).

Buchu is a resprouting shrub endemic to the Cape. Revisions by Pillans (1950) and Spreeth (1976) clarified the taxonomy of *Agath-*

osma betulina and related species but no published biosystematic studies are available. The essential oil components are well known (e.g. Kaiser et al., 1975; Posthumus et al., 1996) but the chemotaxonomic study of Collins et al. (1996) was the first to provide details of a chemical distinction between *Agathosma betulina* and the closely related *Agathosma crenulata* (L.) Pillans (oval leaf buchu), as well as their putative hybrids. *Agathosma crenulata* is less desirable because of potentially harmful levels of pulegone, which occur as the main compound in *Agathosma crenulata* oil (more than 30%) but less than 5% in *Agathosma betulina* oil. No information is available on the variation in the main flavonoids (diosmin and hesperidin) despite their importance in quality control of buchu products (El-Shafae and El-Domiaty, 2001). Aspects of the autecology, genetics and chemical variation in *Agathosma betulina* are currently under investigation.

3.2. *Aloe ferox* Mill. (Asphodelaceae)-bitter aloe, Cape aloe

Aloe ferox is one of only a few plants depicted in San rock paintings (Reynolds, 1950). The bitter latex, tapped from the leaves by a traditional method and exported to Europe since 1761 (Marloth, 1915; Kruger and Beyers, 1977; Robertson, 1979; Forbes, 1986), is known commercially as "Cape aloes". It has a long history of use in Africa and Europe as laxative medicine and is considered to have bitter tonic, anti-arthritic and anti-inflammatory properties (Newall et al., 1996; Blumenthal et al., 1998; Wichtl and Bisset, 2000; ESCOP, 2003). The laxative effect is due to anthrone-*C*-glycosides, of which aloin (syn. barbaloin) is the main compound (Van Wyk et al., 1995). Aloin occurs in tapped and dried leaf juice of *Aloe ferox* (so-called "Cape aloes") as a 1:1 mixture of aloin A and aloin B, at levels of about 10–28% dry weight (Van Wyk et al., 1995). In recent years, the inner leaf parenchyma has become popular for skin care products and tonic drinks.

The taxonomy of *Aloe ferox* is well known (Reynolds, 1950; Glen and Hardy, 2000; Van Wyk and Smith, 2003) and the species limits have been broadened to include *Aloe candelabrum* A.Berger, which is morphologically and chemically almost identical (Viljoen et al., 1996). Variation in the phenolic compounds is well studied (Van Wyk et al., 1995). The gel polysaccharides are known to be of the arabinogalactan and rhamnogalacturonan types (Mabusela et al., 1990) but hardly any research has been done on the leaf gel components or their claimed biological activities. *Aloe ferox* gel differs substantially from that of *Aloe vera* L. (notably in the absence of acetylated sugars) but limited details are available (O'Brien, 2006; unpublished M.Sc. Thesis, University of Johannesburg). Only wildcrafted material is currently used, apparently without any damage to natural populations (Newton and Vaughan, 1996), but the situation may change if there is a strong increase in demand. It may be possible to develop selections and cultivars with superior growth and quality. Some genetic markers have been studied (Van der Bank et al., 1995a; Van der Bank and Van Wyk, 1996); markers such as RFPL, applied to gel identification of *Aloe* species by Shioda et al. (2003), may be useful to guide selection work.

3.3. *Artemisia afra* Jacq. ex Willd. (Asteraceae)-wild wormwood

This plant is one of the oldest and best-known of all the indigenous medicines in southern Africa and further north, up to Ethiopia. An exceptionally wide diversity of uses has been recorded (Dykman, 1908; Watt and Breyer-Brandwijk, 1962; Hutchings et al., 1996; Van Wyk et al., 1997; Neuwinger, 2000; Von Koenen, 2001), including the treatment of colds, influenza, cough, sore throat, asthma, pneumonia, blocked nose, stomach ailments, colic, flatulence, constipation, gastritis, poor appetite, heartburn, internal parasites, measles, headache, earache, gout, diabetes, malaria and wounds. The plant is a popular bitter tonic and appetite stimulant in the Cape region of South Africa (Dykman, 1908; Rood, 1994; Thring and Weitz, 2006).

The volatile oil is exceptionally variable (Graven et al., 1990; Lawrence, 1996; Viljoen et al., 2006), depending on the geographical origin. It is considered to be a useful substitute for armois oil. Often present are 1,8-cineole (eucalyptol), α-thujone, β-thujone, camphor and borneol, together with some sesquiterpenoids such as chrysanthenyl acetate. Ethiopean oil yielded yomogi alcohol and artemisyl acetate as dominant constituents (Worku and Rubiolo, 1996). Several sesquiterpene lactones (guaianolides and glaucolides) have been isolated from above-ground parts (Jakupovic et al., 1988). Non-volatile constituents also include triterpenes (α-amyrin, β-amyrin and friedelin) and alkanes (ceryl cerotinate and *N*-nonacosane) (Silbernagel et al., 1990), as well as surface flavonoids (methyl ethers of luteolin) (Wollenweber et al., 1989).

Artemisia afra has demonstrated antimicrobial (Graven et al., 1992; Gundidza, 1993; Rabe and Van Staden, 1997; Mangena and Muyima, 1999; Huffman et al., 2002; Jäger, 2003; Motsei et al., 2003; Van Vuuren and Viljoen, 2006; Viljoen et al., 2006; Vagionas et al., 2007), antioxidant (Graven et al., 1992; Burits et al., 2001), antimalarial (Weenen et al., 1990; Kraft et al., 2003; Clarkson et al., 2004; Gathirwa et al., 2007), anti-nematodal (McGaw et al., 2000), cardiovascular (hypotensive) (Guantai and Addae-Mensah, 1999), cytotoxic (Jenett-Siems et al., 2002) and sedative (Nielsen et al., 2004; Stafford et al., 2005) effects. Acute and chronic toxicity was studied by Mukinda and Syce (2007), who recorded acute intraperitoneal and oral LD_{50} values in mice of respectively 2.45 and 8.96 g/kg of aqueous *Artemisia* extract (which represented 10% of the herb, w/w). In rats, a low chronic toxicity potential was demonstrated over a period of 3 months, with daily doses of 0.1 and 1.0 g/kg of aqueous extract. The chemotype of *Artemisia* and the level of thujone were not recorded. In humans, high doses of thujone can cause confusion, convulsions and coma but selected chemotypes (especially low thujone clones) are already grown on a small scale. The molecular genetics of *Artemisia afra* is currently under investigation in an attempt to gain insight into the regulatory mechanisms of artemisinin biosynthesis. In a comparison of *Artemisia afra* and *A. annua*, Van der Kooy et al. (2008) showed the value of a metabolomics approach for quality control purposes.

3.4. *Aspalathus linearis* (Burm.f.) R. Dahlgren (Fabaceae)-rooibos tea

Rooibos tea is a traditional herbal tea of the Khoi-San people of the Cedarberg region of the Cape. Commercialization started in 1904 and in 2003 exports to Germany alone exceeded local consumption. Rooibos tea has become popular as a health drink (Watt and Breyer-Brandwijk, 1962; Van Wyk et al., 1997; Burger and Wachter, 1998; Van Wyk and Gericke, 2000; Van Wyk and Wink, 2004) and as an ingredient in cosmetics. There is increasing evidence of anti-mutagenic and antioxidant effects (Von Gadow et al., 1997; Standley et al., 2001; Joubert et al., 2003; Marnewick et al., 2003, 2005). An animal study suggested the prevention of age-related accumulation of lipid peroxidases in the brain (Inanami et al., 1995). Effects on cell division (Lamoš ová et al., 1997) and dermatological conditions (Shindo and Kato, 1991) suggest a rationale for the cosmetic use of rooibos tea extracts. See this volume for a more detailed review.

Aspalathus linearis is exceptionally variable in its morphology (Dahlgren, 1968, 1988) and phenolic chemistry (Rabe et al., 1994; Van Heerden et al., 2003). The chalcone aspalathin is the main

phenolic compound and is used for quality control (Joubert, 1996; Bramati et al., 2002, 2003). The level varies greatly, from 1 mg/g for fermented tea up to 50 mg/g for green (unfermented) tea. The species is morphologically diverse and several different flavonoids are found in the main wild tea types. Considerable genetic diversity was detected by Van der Bank et al. (1995b). Only the so-called Red type or Rocklands type is cultivated, but there is a renewed interest in harvesting some of the wild types for niche markets (Van Wyk et al., 1997). In view of the large variation in the phenolic compounds of wild tea types (Van Heerden et al., 2003), the metabolomics approach may be useful in exploring the chemical rationale behind quality and flavour. Aspects of the seed biology, especially the relation between seed structure, dormany, germination and early seedling growth, were studied by Kelly and Van Staden (1985, 1987). Studies of the autecology and the role of fire in the regeneration of populations could be of value in further crop development.

3.5. *Cyclopia genistoides (L.) R.Br. (Fabaceae)-honeybush tea*

Honeybush tea is a health beverage that has been wild-harvested in parts of the Cape for centuries. The original product was made from *Cyclopia genistoides* (Marloth, 1925), a small shrub with narrow leaflets. The industry is small but is rapidly expanding, largely due to the work of De Lange (1997), who developed four species (*Cyclopia genistoides*, *Cyclopia intermedia* E. Mey., *Cyclopia subternata* Vogel and *Cyclopia sessilifolia* Eckl. & Zeyh.) into crop plants.

A detailed revision of the genus *Cyclopia* (Schutte, 1997) has resolved the species concepts but no biosystematic studies have yet been undertaken. As is the case with *Aspalathus linearis*, the fire-survival strategy (Schutte et al., 1995) and reproductive biology of these fynbos plants needs further study. Some species and populations are resprouters (they survive fire and sprout from the woody base) while others are reseeders—they are killed by fire and re-establish from seed. The seed physiology and seed germination of *Cyclopia* have been studied in detail (Sutcliffe and Whitehead, 1995; Whitehead and Sutcliffe, 1995) and some of the principles are already applied in commercial propagation. The phenolic constituents of honeybush tea were first studied by De Nysschen et al. (1996), who identified mangiferin and two flavonoids as the main compounds in practically all the species. Further work by Ferreira et al. (1998) described the total phenolic complexity in more detail, including the polyphenols in *Cyclopia intermedia* (Kamara et al., 2003). Metabolomics may be a useful approach to learn more about the relation between chemical compounds, flavour profiles, processing methods and tea quality.

3.6. *Harpagophytum procumbens (Burch.) DC. ex Meissn. (Pedaliaceae)-devil's claw*

Devils claw is an important traditional medicine and tonic of the indigenous people of the countries surrounding the Kalahari region of southern Africa (Angola, Botswana, Namibia, South Africa and Zimbabwe) but there is a surprising lack of historical records (Van Wyk et al., 1997; Van Wyk and Gericke, 2000). Dried secondary roots of this widely distributed perennial are used, mainly against arthritis, painful joints, dyspepsia and loss of appetite (Newall et al., 1996; Blumenthal et al., 1998; Wichtl and Bisset, 2000; ESCOP, 2003). Clinical studies, reviewed by Wegener (2000), Chrubasik et al. (2003) and Gagnier et al. (2004) have confirmed the mild analgesic and anti-inflammatory properties, usually ascribed to the iridoid glycosides (mainly harpagoside, with smaller amounts of harpagide and procumbide). Commercial product contains between 0.5% and 3% harpagoside. Other compounds (such as phytosterols and sugars) may also play a role, as total extracts are more active than the individual iridoids (Fiebich et al., 2001; Kaszkin et al., 2004). A paper by Stewart and Cole (2005) gives details about all aspects of the product and its commercial harvesting.

The basic taxonomy of *Harpagophytum* is known (Ihlenfeldt and Hartmann, 1970), but there is a need for biosystematic studies. The circumscription of some of the species and infraspecific taxa is not clear and the full morphological and chemical diversity remains to be explored. The taxa described by Ihlenfeldt and Hartmann (1970) include two species and five subspecies: *Harpagophytum procumbens* subsp. *procumbens*, *Harpagophytum procumbens* subsp. *transvaalensis* Ihlenf. & H.Hartm., *Harpagophytum zeyheri* Decne. subsp. *zeyheri*, *Harpagophytum zeyheri* subsp. *schijffii* Ihlenf. & H.Hartm. and *Harpagophytum zeyheri* subsp. *sublobatum* (Engl.) Ihlenf. & H.Hartm. Studies in our laboratory showed that harpagoside may be completely absent from some populations of *H. zeyheri* despite the fact that this species is regarded as an acceptable alternative to *Harpagophytum procumbens* (Czygan and Krüger, 1977). Chemical variation at population level should be studied over the entire distribution range of the various taxa. Several studies have focused on the sustainability of harvesting and propagation methods but a deeper understanding of the autecology and reproductive biology of *Harpagophytum* species will be of considerable value as a source of basic information to guide ongoing crop development and propagation protocols. Recently there has been a considerable amount of tissue culture work done on *Harpagophytum* by the Plant Research Centre, University of KwaZulu-Natal in Pietermaritzburg, as well as crop development work by the University of Munster, Germany.

3.7. *Hoodia gordonii (Masson) Sweet ex Decne (Apocynaceae)-hoodia, ghaap*

The use of *Hoodia* species to suppress hunger and thirst appears to be an ancient and widespread practise of the Khoi-San people that was first recorded by Marloth (1932). The appetite-suppressant effect is due to a patented pregnane compound known as P57 (Van Heerden et al., 1998). *Hoodia* has become an interesting test case for the idea of financial compensation to rural communities for intellectual property rights (in this case, benefit-sharing with Khoi-San communities). The USA-based company Pfiser has announced that they are not proceeding with clinical trials to develop an anti-obesity drug but large-scale commercial developments are nevertheless underway.

The genus *Hoodia* has been taxonomically revised by Whyte and Sloane (1937) and more recently by Bruyns (1993), with contributions on the nomenclature published by Plowes (1992, 1996). The species are beautifully illustrated and described in a recent book on the Stapelieae (Bruyns, 2005). *Hoodia* species are known to have small and widely dispersed populations that make them vulnerable to overexploitation. The distinct morphological differences between populations may also be reflected in chemical patterns but no chemotaxonomic or biosystematic information has hitherto been published. A detailed review is published elsewhere in this volume.

3.8. *Hypoxis hemerocallidea Fisch. & C.A. Mey. (Hypoxidaceae)-inkomfe, "African potato"*

The so-called *African potato* (a recent name created for commercial reasons) is a well-known Sotho and Zulu medicinal plant but surprisingly little traditional knowledge has been documented. Weak infusions and decoctions are taken as tonics against wasting diseases, including tuberculosis and cancer (Van Wyk and

Gericke, 2000). *Hypoxis* has been used traditionally for benign prostatic hypertrophy and urinary tract infections, and as a laxative and vermifuge (Van Wyk et al., 1997). The traditional use for benign prostatic hypertrophy is ascribed to sitosterols (mainly β-sitosterol), which decrease testosterone levels through inhibition of 5-α reductase, or by decreasing the binding of dihydrotestosterone within the prostate (Bruneton, 1999). The so-called "African potato" or inkomfe (*Hypoxis hemerocallidea*) has become a household name (Drewes and Horn, 1999) but extracts of the plant, including rooperol (Drewes et al., 1984) are no longer used for its patented (Drewes and Liebenberg, 1983) application against cancer. Likewise, the phytosterols used in immune-boosting products are no longer obtained from *Hypoxis hemerocallidea* (Pegel, 1973, 1997) but the corms of the plant are nevertheless processed on a small scale for various traditional tonics.

Taxonomic studies of *Hypoxis* are underway (Singh, 2003, cited in Germishuizen and Meyer, 2003) but the morphological, chemical and genetic diversity in *Hypoxis hemerocallidea* (formerly known as *H. rooperi*) remains unexplored. The plant is easy to grow but difficult to propagate, so that fundamental studies relating to the reproductive biology and seed physiology are obvious priorities. A considerable amount of work has already been done on tissue culture and seed germination (Page and Van Staden, 1984, 1986, 1987; Hammerton and Van Staden, 1988; Hammerton et al., 1989).

3.9. *Lippia javanica (Burm.f.) Spreng. (Verbenaceae)-fever tea*

Lippia javanica is widely used as a tea to treat fever, coughs, colds and bronchitis (Watt and Breyer-Brandwijk, 1962; Smith, 1966; Hutchings et al., 1996; Van Wyk et al., 1997; Van Wyk and Gericke, 2000). Other traditional uses that have been recorded include stomach problems, influenza, measles, malaria and headache (Hutchings and Van Staden, 1994; Van Wyk et al., 1997; Van Wyk and Gericke, 2000). Strong infusions are also used topically to treat rashes, scabies and lice. Hot leaf infusions (sometimes with milk) are taken as a general health tea. A review of the traditional uses, chemistry and pharmacology was presented by Pascual et al. (2001).

This highly aromatic plant is rich in volatile oil that contains carvone, myrcene, myrcenone, caryophyllene, linalool, *p*-cymene, piperitenone, ipsenone and ipsdienone (e.g. Neidlein and Staehle, 1974; Mwangi et al., 1992; Chagonda et al., 2000; Manenzhe et al., 2004; Viljoen et al., 2005). The oil composition varies considerably within and between populations and five different chemotypes were identified by Viljoen et al. (2005), with myrcenone, carvone, piperitenone, ipsenone or linalool, respectively as main compounds. The related *Lippia scaberrima* Sond. is also used in much the same way but the oil contains mainly carvone, 1,8-cineole and limonene (Combrinck et al., 2006). Iridoid glycosides (Rimpler and Sauerbier, 1986) and toxic triterpenoids (icterogenins) such as lantadene A and icterogenin have been detected in some *Lippia* species (Barton and De Mayo, 1954).

The essential oil of *Lippia javanica* shows moderate antimicrobial activity against respiratory pathogens (Manenzhe et al., 2004; Viljoen et al., 2005) and promising anti-inflammatory activity (Frum and Viljoen, 2006). It may be interesting to study the possible role of non-volatile components, especially in terms of fever-reducing and possible pain-relieving activities. Animal poisoning and photosensitisation have been ascribed to the icterogenins (Watt and Breyer-Brandwijk, 1962; Van Wyk et al., 2002; Kellerman et al., 2005). The oil has moderate repellent activity against mosquitoes (Omolo et al., 2004). The paper by Viljoen et al. (2005) has highlighted the need for chemotaxonomic and biosystematic studies.

3.10. *Mesembryanthemum tortuosum L. [syn. Sceletium tortuosum (L.) N.E. Br.] (Mesembryanthemaceae)-sceletium, kougoed*

Kougoed, *kanna*, *channa* or sceletium is a traditional sedative of the Khoi-San people of the dry western regions of South Africa. The uses and properties of the plant have been known ever since it was first documented by the Cape Governor, Simon van Stel, in 1685 (Hartwich, 1911; Zwicky, 1914; Watt and Breyer-Brandwijk, 1962; Watt, 1967; De Wet and Pheiffer, 1979; Forbes, 1986; Smith et al., 1996a; Van Wyk and Gericke, 2000; Van Wyk and Wink, 2004; Scott and Hewett, 2008) but it is only recently that crop and product development have been initiated. The activity of the plant is ascribed to mesembrine and other alkaloids, which have been shown to act as serotonin reuptake inhibitors (Gericke and Van Wyk, 1997).

The plant is a small, short-lived perennial succulent with fleshy leaves that become papery and sceletonised in the dry season, hence the scientific name *Sceletium*. A large number of doubtful species have been described but a detailed taxonomic revision is available (Gerbaulet, 1996). At the generic level, the relationships and age of basal lineages within the family (and specifically the subfamily Mesembryanthemoideae) have been reported by Klak et al. (2004). A recent study has shown that the entire subfamily represents a single genus (Klak et al., 2007) and all the existing genera were formally subsumed under the genus *Mesembryanthemum*. A survey of alkaloids in the family (Smith et al., 1996a; Gaffney, 2006) showed that several genera and species produce alkaloids. The species of commercial interest is *Mesembryanthemum tortuosum*, a highly variable plant with a wide distribution range (Gerbaulet, 1996). It differs from the seven close relatives in having straight secondary veins, prominent idioblasts, incurved leaf tips and imbricate leaves (Gerbaulet, 1996). Variation studies in our laboratory has shown that some populations of *Mesembryanthemum tortuosum* are practically devoid of mesembrine-type alkaloids, while others have high yields of up to 2.4% of dry weight. As with so many African plants, the full morphological, chemical and genetic diversity of the species remains unknown, despite commercial interests. A more detailed review of *Mesembryanthemum tortuosum* can be found elsewhere in this volume.

3.11. *Pelargonium sidoides DC. (Geraniaceae)-umckaloabo, rabas*

Traditional knowledge about this commercially important plant is poorly recorded (Smith, 1895; Van Wyk and Gericke, 2000). The ethnobotanical and commercial history of the plant is reviewed by Brendler and Van Wyk (this volume). The tuberous roots are the raw material for an important German phytomedicine used mainly to treat acute bronchitis and infections of the upper respiratory tract (e.g. Matthys et al., 2003; Agbabiaka et al., 2008). Various biological activities have been reported, including immune stimulation (Kayser et al., 2001), NO-induction and antibiotic effects (Kayser and Kolodziej, 1997; Kolodziej et al., 2003). Recent studies showed clinically significant effects on nasal epithelial cells (Neugebauer et al., 2005) and activity against mycobacteria (Seidel and Taylor, 2004; Mativandlela et al., 2007).

The medicinal properties are ascribed to at least eight different coumarins, of which umckalin and 5,6,7-methoxycoumarin are useful marker compounds (Kayser and Kolodziej, 1994, 1995, 1997; Kolodziej and Kayser, 1998; Kayser et al., 2001). Also present in the roots are gallic acids and methyl esters of gallic acids, as well as flavonoids (quercetin), flavan-3-ols (catechin, gallocatechin) and phytosterols (sitosterol-3-gluoside).

The plant is a small perennial herb with tuberous rhizomes, rounded to heart-shaped and slightly silky leaves on long peti-

oles, and small tubular flowers that are dark maroon red to almost black (Van der Walt, 1988; Dreyer and Marais, 2000; Van Wyk and Wink, 2004). The closely related *Pelargonium reniforme* is morphologically very similar but has pink flowers (Van der Walt, 1977; Dreyer and Marais, 2000). Morphological distinction of the dried product is extremely difficult, so that chemical analysis is the only reliable method. The major constituents in *Pelargonium sidoides* are umckalin and its 7-*O*-methylether (=5,6,7-trimethoxycoumarin) but these compounds are characteristically low or absent in *Pelargonium reniforme* (Kolodziej and Kayser, 1998). Aspects of the micropropagation and morphological diversity of the species were reported by Lewu et al. (2006, 2007). A detailed study by White et al. (2008) has given valuable new insights into the effects of environmental stimuli on the level of umckalin in roots of wild and cultivated plants. No published information is as yet available on the basic biology, biosystematics and genetic diversity of *Pelargonium sidoides* and its relation with *Pelargonium reniforme* despite the commercial importance of these plants.

3.12. *Siphonochilus aethiopicus (Schweinf.) B.L.Burtt (Zingiberaceae)-African ginger*

African ginger is one of the most important and most popular of all traditional medicinal plants of southern Africa (Watt and Breyer-Brandwijk, 1962; Van Wyk et al., 1997; Van Wyk and Gericke, 2000; Van Wyk and Wink, 2004). The rhizomes and roots are used for a variety of ailments, including coughs, colds, asthma, headache, candida and malaria (Watt and Breyer-Brandwijk, 1962; Van Wyk et al., 1997; Van Wyk and Gericke, 2000; Crouch et al., 2000).

African ginger is a deciduous geophyte with large, hairless leaves, a cone-shaped rhizome and spectacular pink flowers. Most plants are bisexual, and they have much larger flowers than female plants. The small, berry-like fruits are borne below or above the ground (Kam, 1980; Gordon-Gray et al., 1989; Smith, 1998; Van Wyk et al., 1997; Van Wyk and Gericke, 2000; Crouch et al., 2000; Van Wyk and Wink, 2004). The plant is morphologically uniform but genetically very polymorphic (Makhuvha et al., 1997).

No comprehensive taxonomic studies have yet been done on the genus *Siphonochilus* and related genera and available knowledge comes mainly from Flora treatments (Smith, 1998). The exact distribution of the species in Africa remains poorly known and no comprehensive distribution maps have yet been published. The main commercial species, *Siphonochilus aethiopicus*, is relatively well known as a result of its popularity in traditional medicine and concerns about it conservation status. It is often quoted as being locally extinct in some parts of South Africa as a result of overexploitation. However, the plant is exceptionally easy to propagate and cultivate, so that small-scale cultivation is already underway. Aspects of the reproductive biology were studied by Gordon-Gray et al. (1989) but much interesting work remains to be done. The major chemical constituents are sesquiterpenoids of the furanoid type (Van Wyk et al., 1997; Holzapfel et al., 2002) and chemical variation studies are ongoing. The composition of the essential oil was described by Viljoen et al. (2002). It contains high concentrations (up to 0.2% of dry weight) of a single compound loosely referred to as *Siphonochilus sesquiterpenoid* or siphonochilone (Van Wyk et al., 1997; Holzapfel et al., 2002; Viljoen et al., 2002). Extreme genetic diversity was observed in a natural population (Makhuvha et al., 1997), allowing for genetic fingerprinting at the clonal level. Further work showed that most of the southern provenances represent a single clone (Makhuvha et al., unpublished results) confirming traditional knowledge (C. Mutwa, personal communication to BEvW) that African ginger (*isiphephetho* in isiZulu) is an ancient Zulu crop plant of tropical African origin.

3.13. *Sutherlandia frutescens (L.) R.Br. [syn. Lessertia frutescens (L.) Goldblatt & J.C.Manning] (Fabaceae)-cancer bush, sutherlandia*

The traditional claim that cancer bush "can be used for almost any disease" is perhaps the reason why this plant has never in the past received the serious attention that it deserved. The wide diversity of historical uses has been documented by Smith (1895), Watt and Breyer-Brandwijk (1962) and in more detail by Van Wyk and Albrecht (this volume). The plant is widely used by many cultural groups for fever, poor appetite, unspecified wasting diseases, indigestion, gastritis, oesophagitis, peptic ulcer, dysentery, cancer tonic (prevention and treatment), diabetes, colds, influenza, cough, asthma, chronic bronchitis, kidney and liver conditions, rheumatism, heart failure, urinary tract infections and stress and anxiety. Recent clinical anecdotes suggest dramatic improvements in the quality of life in HIV/AIDS patients, apparently by counter-acting the muscle-wasting (cachexia) effect of AIDS. A detailed safety study has been completed by the Medicine Research Council of South Africa, showing no signs of toxicity in more than 50 parameters tested (Seier et al., 2002). Like-wise, a clinical (phase I) study (Johnson et al., 2007) found that 800 mg/day was well tolerated, with no indications of toxicity.

Chemical compounds isolated from the plant include pinitol, triterpenoid saponins (e.g. SU1), flavonoids and several free amino acids, including L-canavanine and GABA. Canavanine is a potent L-arginine antagonist and has documented anticancer (Swaffar, 1995; Crooks and Rosenthal, 1994) and antiviral activity, including inhibition of the influenza virus and retroviruses (Green, 1988). Canavanine is also an inhibitor of nitric oxide synthase and has potential for the treatment of septic shock. Pinitol is a known anti-diabetic agent that may have an application in treating wasting in cancer and AIDS (Ostlund and Sherman, 1996). Possible anti-diabetic uses have been reviewed by Sia (2004). GABA is an inhibitory neurotransmitter that could partly account for the use of *Sutherlandia* for anxiety and stress (Moteetee and Van Wyk, 2007). Recent studies have reported anti-cancer and anti-mutagenic effects (Tai et al., 2004; Reid et al., 2006; Stander et al., 2007), anti-HIV activity (Harnett et al., 2005) as well as stress-relieving properties (Prevoo et al., 2004; Smith and Myburgh, 2004). The complex mixtures of saponins and flavonoids are the subject of ongoing studies.

Sutherlandia represents an intricate species complex with countless regional forms, genotypes and chemotypes. The basic taxonomy of Phillips and Dyer (1934) was revised by Moshe (1998), who recognized only two species, with several subspecies. Goldblatt and Manning (2000) reduced the genus into synonymy under *Lessertia*, and made the new combination *Lessertia frutescens* (L.) Goldblatt & J.C. Manning. This may be correct, but there are as yet no convincing morphological or molecular systematic studies to show that *Sutherlandia* is indeed nested within the genus *Lessertia* as the proposed new classification system suggests. Both names (*Sutherlandia frutescens* and *Lessertia frutescens*) are therefore widely used for the same plant.

Genetic diversity in *Sutherlandia* was explored using enzyme electrophoresis (Moshe et al., 1998). It was found that the distinct morphological diversity (especially in fruit characters) is not reflected in the enzyme patterns. However, the idea that some hairy forms of *Sutherlandia frutescens* resulted from introgression with *Sutherlandia tomentosa* Eckl. & Zeyh. was supported by the study. The complexity in terpenoid and flavonoid patterns was first reported by Moshe (1998) and further work is ongoing.

3.14. *Warburgia salutaris (Bertol.f.) Chiov.* *(Canellaceae)-pepperbark tree*

Knowledge about this traditional medicine is surprisingly poorly recorded considering its obvious importance and popularity. It is one of the great tonics and panaceas of southern Africa—the specific name *salutaris* means "salutory to health". The bark is usually taken orally in a powdered form, or as infusions and decoctions. *Warburgia* is used as a tonic for all health conditions, including fever, malaria, colds, influenza, venereal diseases, abdominal pain, constipation, cancer, rheumatism, stomach ulcers, headache, as an expectorant in coughs, and as a natural antibiotic to treat chest infections (Hutchings et al., 1996; Van Wyk and Gericke, 2000). Tablets made from the leaves are used as a natural antibiotic, thought to be effective against oral and oesophageal thrush.

The basic taxonomy of *Warburgia* species was revised by Verdcourt (1955, 1990) and Codd (1976) but the relationships between the species and subspecies have remained poorly known. The described taxa are *Warburgia elongata* Verdc., *Warburgia salutaris*, *Warburgia stuhlmannii* Engl., *Warburgia ugandensis* Sprague subsp. *ugandensis* and *Warburgia ugandensis* subsp. *longifolia* Verdc. There are no modern studies exploring the circumscription and status of these taxa, but work is underway at the University of KwaZulu-Natal to study the genetic variation in *Warburgia*. Preliminary results revealed genetic differences in support of the idea of three taxa.

The bark contains drimane sesquiterpenoids such as warburganal and polygodial, both of which are known to be active against candida. Polygodial is potentially useful in clinical medicine as an adjuvant to treatment with antibiotics and antifungals that have poor membrane permeability (Iwu, 1993). The compounds found in *Warburgia salutaris* (Mashimbye et al., 1999) include warburganal, mukaadial, salutarisolide, polygodial and isopolygodial, as well as muzigadial (Rabe and Van Staden, 2000). There are numerous phytochemistry reports based on single samples but possible differences between populations and species have hardly received any attention. Kioy et al. (1990) found no consistent differences in the sesquiterpenes and leaf volatile oils between *Warburgia ugandensis* and *Warburgia stuhlmannii*. A thorough biosystematic study of the genus *Warburgia* over its entire distribution range in Africa would clearly yield useful results.

3.15. *Xysmalobium undulatum (L.) W.T.Aiton* *(Apocynaceae)-uzara*

This important medicinal plant has a long history of traditional and commercial use, not only in South Africa (where it has been cultivated since 1904), but also in Germany, where it was introduced into the pharmaceutical market in 1911 (Ghorbani et al., 1997). The traditional uses have been recorded by Thunberg (Forbes, 1986), Watt (1935), Watt and Breyer-Brandwijk (1962), Pujol (1990), Hutchings and Van Staden (1994), Hutchings et al. (1996), Van Wyk et al. (1997) and Von Koenen (2001). Decoctions of the bitter roots have been used since early times for stomach cramps, diarrhoea, colic and afterbirth cramps, while powdered root is sniffed to treat headache and hysteria or applied to wounds and abscesses. In Germany, extracts are used commercially against non-specific, acute diarrhoea.

The active ingredients are cardenolide glycosides, the structures of which were finally elucidated by Ghorbani et al. (1997). Uzarin and xysmalorin are the major compounds, with smaller amounts of allouzarin and alloxysmalorin. These glycosides are known for their inhibitory effect on intestinal motility and their digitalis-like effects on the heart at high doses (e.g. Wichtl and Bisset, 2000). Recent investigations focused on antibacterial and antifungal activity (Buwa and Van Staden, 2006), possible CNS-activity (Stafford et al., 2005), antibacterial, antioxidant and fibroblast growth stimulation activities (Steenkamp et al., 2004), serotonin reuptake inhibition (Nielsen et al., 2004) and antiplasmodial activity (Clarkson et al., 2004). The extent of variation in the main cardiac glycosides is not yet known. A paper dealing with *Xysmalobium undulatum* is included in this volume.

4. Discussion

The commercialization of southern African medicinal plants is a process that has been rapidly gaining momentum during the last 10 years. Before 1995, only nine of the 15 plants reviewed here have been developed to any extent. These are *Agathosma betulina*, *Aloe ferox*, *Aspalathus linearis*, *Cyclopia* species, *Harpagophytum procumbens*, *Hypoxis hemerocallidea*, *Lippia javanica*, *Pelargonium sidoides* and *Xysmalobium undulatum*). The remaining six (*Artemisia afra*, *Hoodia gordonii*, *Mesembryanthemum tortuosum*, *Siphonochilus aethiopicus*, *Sutherlandia frutescens* and *Warburgia salutaris*) are newcomers to the formal pharmaceutical market. The recent commercial interests in these species have also sparked a rapid increase in scientific research. Twelve years ago, there were hardly any scientific papers on the pharmaceutical activity of these plants, as is shown in Table 2.

The need for fundamental studies, and specifically the biosystematics of commercially relevant species, was discussed by Van Wyk (1996) who proposed that "biosystematics can play an important role to ensure that we grasp the commercial opportunities provided by our genetically diverse flora". These sentiments were echoed by Smith et al. (1996b), who provided a list of activities of the Plant Systematics Stimulation Programme (later the Working Group for Plant Systematics) to promote systematics research and concluded that "With its unsurpassed botanical diversity, southern Africa holds natural resources of global significance". The development of medicinal plants species into new products and new crops is a complicated process that requires a multidisciplinary approach, involving biosystematics, ethnobotany, organic chemistry, pharmacology and horticulture. There is a need for taxonomic and systematic studies of the plants and their relatives in order to better understand the full genetic and metabolic diversity at population and clonal levels, ethnobotanical studies to document and explore the socio-cultural context of the medicinal plants, chemical studies to identify the active chemical compounds or marker compounds, pharmacological studies to determine the mode of action, horticultural or autecological studies to find out if the plants are suitable for large-scale production or sustainable harvesting and finally, studies of the reproductive biology of the plants to develop propagation protocols and to guide crop development. The starting point for new innovations in the future will be fundamental biological knowledge about the species, including their phylogeny, taxonomy, genetics, chemical variation and reproductive biology.

Acknowledgements

This review is based on a lecture presented at a symposium on African plants during the 2005 Annual Meeting of the Botanical Society of Japan in Toyama, organized by Prof Toshiya Muranaka (RIKEN Plant Science Center and Yokohama City University). Funding by the National Research Foundation of South Africa and the University of Johannesburg for ethnobotanical and chemosystematic studies of South African medicinal plants is gratefully acknowledged.

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