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Mondia whitei (Apocynaceae): A review of its biological activities, conservation strategies and economic potential

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Abstract

Globally, the commercialisation of plants as observed in their uses by many industries such as the cosmeceutical, nutraceutical and pharmaceutical ones is gaining more interest and popularity. *Mondia whitei* is a popular medicinal plant which is endemic to Africa. Since antiquity, *M. whitei* has been used by African people to treat various ailments. The roots were used for the treatment of anorexia, stress, bilharzia and sexual dysfunction as well as for general aches and pains. Researchers have evaluated the efficacy of most of these claims by screening the *M. whitei* for biological activities such as antimicrobial, anti-inflammatory and anthelmintic as well as aphrodisiac efficacy. Furthermore, *M. whitei* has horticultural, nutritional and other socio-cultural values as reported in countries such as South Africa, Nigeria, Zimbabwe, Kenya, Uganda and Malawi. As a result of its numerous uses across the African continent, we attempt to explore and assess the economic potential of *M. whitei* with emphasis on medicinal values. The root of *M. whitei* is the most popular organ used in traditional medicine; consequently, this has resulted in the species becoming rare or threatened with extinction in the wild. Several authors have suggested solutions such as plant or plant part substitution to overcome the over-harvesting problem. The application of biotechnology techniques such as micropropagation and hairy roots also remain viable options which are presently being utilised to a lesser extent. Nevertheless, the sustainable harvesting and feasible conservation strategy for the species remains a major challenge. It is strongly recommended that in as much as the economic potential of *M. whitei* should be exploited, more detailed attention and studies should be geared towards its conservation. In order to ensure sustainable use and to derive maximum economic benefits, it is necessary to have empirical information detailing its ethno-botanical values, conservation status and commercial potential.

Keywords: 2-hydroxy-4-methoxybenzaldehyde; Aphrodisiac; Conservation; Medicinal plant; *Mondia whitei*; South Africa; Traditional medicine

1. Introduction

Mondia whitei (Hook.f.) Skeels is a member of the Apocynaceae (previously in the family Asclepiadaceae), subfamily Periplocoideae. The species was initially placed in the genus *Chlorocodon*, this was later changed to *Mondia* because the former name was a homonym used for a genus of ericacious plants. The genus *Mondia* Skeels consists of two species; *M. whitei* and *Mondia ecornuta* (N.E.Br.) Bullock. (Ross, 1978; Venter et al., 2009). Both species have the same physical appearance however, the structure and number of corona lobes are the distinguishing features between the two species (Venter et al., 2009). *M. whitei* is commonly known as White's ginger, tonic root or umondi/mundi; a Zulu name from which the generic name was derived. Interestingly, the specific epithet '*whitei*' was in honour of the collector Mr A.S White of Fundisweni, Natal who motivated the transfer of the species to the Royal Botanical Gardens, Kew, England for documentation (Ross, 1978).

M. whitei is an endemic African species useful to the populace since ancient time. Some of the important uses of *M. whitei* are medicinal, cultural and nutritional. Most of the plant material is collected from the wild and this has contributed significantly to its vulnerable status. In most countries where *M. whitei* is found, the commercial cultivation of the species is minimal or does not exist

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which has further impacted upon its conservation. In view of the economic potential of *M. whitei* especially the medicinal uses, we decided to search and collect the available information on the species via electronic (search engines) and library searches. This review examines the various studies on *M. whitei* in an attempt to highlight the benefits that may be derived from the plant. From published data, some observed loopholes as well as the neglected research areas on *M. whitei* were also identified for possible attention from researchers. In addition, this review strongly endorses the commercialisation of *M. whitei* in South Africa based on its extensive usage by the local populace. It is hoped that this review will provide useful material to researchers, conservationists, policy makers as well as government agencies that require detailed overview of the general uses, possible conservation methods and economic potential of *M. whitei*.

1.1. Morphology of *M. whitei*

M. whitei is a perennial woody climber reaching 3–6 m high with twining stems which exudes white latex when cut (Fig. 1A). It has characteristic large, oppositely positioned heart-shaped leaves (Fig. 1B). The surface of the leaves are endowed with soft hairs and distinctive star-shaped stipules (Ross, 1978). The attractive flowers are reddish purple in colour and are borne in branched inflorescences (Fig. 1C). Flowers are assumed to be pollinated by flies and are relatively short-lived surviving for 3–4 days. The flowering season ranges from October to March (peaking between November and January) south of the equator and from May to August (peaking in June to July) north of the equator (Venter et al., 2009). *M. whitei* grows from a large, tuberous rootstock and the roots have a very distinct vanilla aroma which has been attributed to the presence of 2-hydroxy-4-methoxybenzaldehyde (Fig. 1D). The roots grow laterally and may spread out just beneath the soil surface covering large areas, making them easy to harvest (Ross, 1978; Van Wyk and Gericke, 2000). The fruit is an ovoid follicle which dehisces to release an estimated 180–320 comose seeds that are wind-dispersed (Ross, 1978). A more comprehensive history, morphology and taxonomy of *M. whitei* is available (Venter et al., 2009).

2. Distribution of *M. whitei*

M. whitei is endemic in almost all African regions with the exception of the northern part of the continent. *M. whitei* predominantly occurs in moist to wet forests. It is found in vegetation types that range from swamp forest, swampy shrubby grassland and riverine forest to disturbed forest, at altitudes from sea level to 1800 m (Venter et al., 2009). In West Africa, the species is commonly found in Guinea, Ghana and

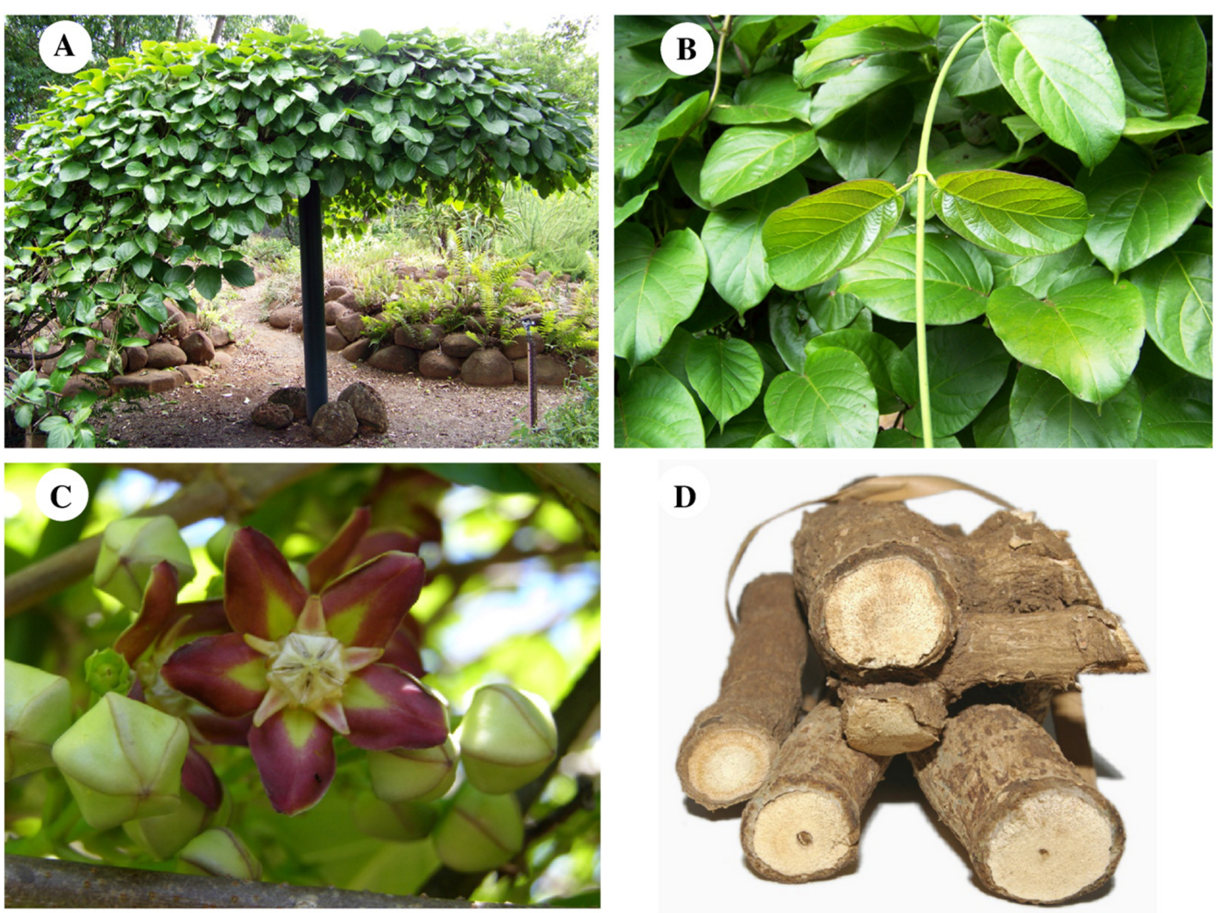

Fig. 1. *Mondia whitei* (A) creeping and well-supported on an iron bar; (B) twining stems with leaves; (C) young buds and fully opened flowers; and (D) mature roots.

Nigeria whereas in the central Africa region, it occurs in Cameroon. Kenya, Tanzania and Uganda are countries where *M. whitei* is found in East Africa (McGeoch et al., 2008; Venter et al., 2009). South Africa, Malawi, Angola, Mozambique and Zimbabwe are southern African countries where this species has been recorded (Venter et al., 2009). In South Africa, *M. whitei* is mainly found in the KwaZulu-Natal and Limpopo Provinces. In KwaZulu-Natal, the species is restricted to the midlands as well as lower, frost-free elevations; often near the coastal areas where colonies are becoming scarce in protected swamps (Crouch et al., 1998a). Herbarium specimens examined by Venter (Venter et al., 2009) indicated locations such as Mkuze Nature Reserve (confluence of Mkuze and Msunduzi rivers), Empangeni village and Mfundisweni (formerly Fundisweni) as areas where *M. whitei* occurs in the Province of KwaZulu-Natal.

3. Uses of *M. whitei*

3.1. Medicinal uses

M. whitei is a versatile plant with many uses which are either documented or passed down to subsequent generations by word of mouth. Across various ethnic groups in Africa, *M. whitei* is known as a mild laxative, to ease abdominal pains, alleviate nausea as well as for the treatment of fever, bilharzia and sexual dysfunction (Crouch et al., 1998a). Besides ancient documentation of the uses of *M. whitei* (Gelfand et al., 1985; Watt and Breyer-Brandwijk, 1962), more recent ethno-botanical surveys continually cite the local use of the species. A root decoction of *M. whitei* is documented to; induce labour in Uganda (Ssegawa and Kasenene, 2007), fight malaria infection in Benin and Nigeria (Hermans et al., 2004; Odugbemi et al., 2007), eradicate worm infestation (anthelmintics) in Nigeria (Idu et al., 2010) and cure male infertility in Cameroon (Focho et al., 2009). In Kenya, a survey showed that *M. whitei* is practically used for many problems, for example; ringworms, skin diseases, stomach worms, heart diseases and asthma (McGeoch, 2004). In addition, the species is used by unspecified groups in South Africa to treat stress and tension in adults (Van Wyk and Gericke, 2000). Stafford et al. (2008) highlighted that South Africans use *M. whitei* to stimulate appetite, as an aphrodisiac, and for treatment of fits in children.

A number of scientific studies involving the use of different solvent extracts of *M. whitei* parts have been performed by various workers. These include biological assays investigating the aphrodisiac, antimicrobial, anti-inflammatory, anti-tyrosinase and antioxidant activities (Table 1). Most of the assays attempt to investigate the efficacy of the plant extracts against major health problems encountered by humans. *M. whitei* extracts have shown great potential in most of the biological activities investigated thus validating most of its traditional uses since ancient times. Particularly, the investigation for aphrodisiac efficacy of *M. whitei* roots, yielded positive results (Lampiao, 2009; Martey and He, 2010). Some aldehydes are cytotoxic against certain types of cancer *in vitro*. As this may be due to inhibition of tyrosinase, it was decided to investigate *M. whitei* for possible anticancer activity against various cell lines (Kintzios and Barberaki, 2004). The efficacy of *M. whitei* extracts against mental, neurological or behavioural problems via *in vivo* and *in vitro* systems has also received intense investigation by our group (RCPGD) in collaboration with the Department of Medicinal Chemistry, University of Copenhagen, Denmark. Recently, a monoterpene lactone (−)-loliolide (4) which was responsible for *in vitro* serotonin transporter (SERT) affinity was isolated (Neergaard et al., 2010). Owing to the unique nature of the isolated compound (4), further studies to elucidate the SERT inhibition mechanism as well as the *in vivo* efficacy are on-going.

Although most studies investigating the biological activity of numerous medicinal species such as *M. whitei* are based on one plant one target approach, traditional medicine often uses the combination of two or more plant extracts at a time. As a result of this practice, a number of studies have also investigated formulations which consisted of *M. whitei* in treatment of sickle cell anaemia (Egunyomi et al., 2009) and sexual dysfunctions (Gundidza et al., 2009). The authors reported favourable results with formulations containing *M. whitei* however, the impact of the *M. whitei* in the observed responses remain very difficult to explain due to the complex nature of the interaction with other plant species in the formulation.

3.2. Nutritional properties

From antiquity, various organ parts of *M. whitei* such as leaves, roots and tubers have been utilised as food. As documented by Gerstner (1941), the Zulus in South Africa use the roots as an appetite stimulant. Several flavoured drinks have been obtained from the roots. During weddings in several West Africa countries, the roots are used to make a beverage similar to ginger beer or are brewed in alcohol to make an energising drink. In South Africa, the root is sometimes cooked with meat to enhance the flavour and also used as a tea (Crouch et al., 1998a; Van Wyk and Gericke, 2000). In Kenya, the roots are eaten fresh or dried, initially tasting rather hot and bitter then slightly sweeter afterwards (Mukonyi, 2002). In Angola, *M. whitei* served as an alternative food for the early Portuguese and their neighbouring locals who boiled the leaves with butter or olive oil serving as a substitute for spinach. In KwaZulu-Natal (South Africa), leaves are eaten as a pot herb or *imifino* and the dried powdered leaves are added to food as a condiment (Crouch et al., 1998a). Mukonyi (2002) reported that *M. whitei* leaves have more nutritional value than other regularly used animal feeds, but it proved unpalatable to goats. Nevertheless, it seemed to increase milk production in Friesian cows. In Uganda, the tubers are commonly consumed; however the taste varies depending on the age of the plant. The young tubers are sweet tasting, whereas mature tubers have a slightly bitter taste probably because of the accumulation of secondary metabolites (McGeoch, 2004).

M. whitei contains vitamins A, D, K and E as well as magnesium, zinc, iron, calcium and protein (Tables 2 and 3). As a result, *M. whitei* may be a readily and affordable alternative source for the prevention of micronutrient deficiencies especially among poor populations. Youkeu (2008) estimated the nutritional value of *M. whitei* to be 280.8 kcal/100 g. In addition, an *in vivo* study to determine the effect of *M. whitei*

Table 1
Pharmacological studies on *Mondia whitei* across various African countries with biological activities assayed and resultant effects.

Country of collection	Part used	Extracting solvent	Biological activity evaluated	Observations and results	Reference
Cameroon	Root bark	Water	Reversible *in vivo* antispermatogenic and antifertility activities	Inhibition of spermatogenesis and reduced fertility	Watcho et al., 2001
Cameroon	Roots	Water	*In vivo* androgenic activity	An increase in serum and intra-testicular testosterone levels after chronic treatment	Watcho et al., 2004
Cameroon	Roots	Hexane	*In vivo* androgenic activity	Had a reversible androgenic effect and potentiate the action of norepinephrine on rat vas deferens	Watcho et al., 2005
Cameroon	Roots	Hexane, methylene chloride: methanol	*In vitro* androgenic activity	Hexane fraction had a significant inhibition against the contractions induced by potassium chloride (KCl) and adrenaline-induced contraction in isolated vas deferens	Watcho et al., 2006
Cameroon	Roots	Hexane, water and methylene chloride	*In vitro* pro-erectile activity	Methylene chloride fraction relaxed the smooth muscle of guinea pig corpus cavernosum pre-contracted with phenylephrine	Watcho et al., 2007a
Cameroon	Roots	Hexane, water	*In vivo* androgenic activity	Extracts caused an increase in mount, intromission and erectile frequencies of the inexperienced male rats	Watcho et al., 2007b
Cameroon	Roots	Water	*In vitro* antioxidant, anti-amylase and anti-lipase activities	No significant bioactivity was detected in the three assays	Etoundi et al., 2010
Cameroon	Roots	Methanol	*In vitro* antioxidant activity (Hydroxyl radical scavenging, ferric ion reducing power and free radical scavenging activity)	Extract had high hydroxyl radical scavenging activity while antioxidant activity in other assays were low	Abdou Bouba et al., 2010
Ghana	Roots	Ethanol	*In vivo* aphrodisiac activity	A dose of 200 mg/kg improved and sustained erection probably through activation/stimulation of nitric oxide synthase (NOS) activity	Quasie et al., 2010
Kenya	Roots	Methanol	*In vitro* tyrosinase-inhibitory activity	Inhibition of the oxidation of L-3,4-dihydroxyphenylalanine (L-DOPA) with ID_{50} of 4.3 µg/ml	Kubo and Kinst-Hori, 1999
Kenya	Roots	Hexane, methanol, water	*In vitro* anti-inflammatory activity	Hexane and methanol extracts had high (above 80%) cyclooxygenase-1 (COX-1) enzyme inhibition	Matu and Van Staden, 2003
Kenya	Roots	Hexane, methanol, water	*In vitro* antibacterial activity	No significant antibacterial activity detected using the agar disc-diffusion assay	Matu and Van Staden, 2003
Kenya	Leaves	Hexane, methanol, water	*In vitro* anti-inflammatory activity	Methanol and water extracts had moderate (above 65%) COX-1 inhibition	Matu and Van Staden, 2003

(continued on next page)

Table 1 (*continued*)

Country of collection	Part used	Extracting solvent	Biological activity evaluated	Observations and results	Reference
Kenya	Leaves,	Hexane, methanol, water	*In vitro* antibacterial activity	No significant antibacterial activity detected in agar disc-diffusion assay	Matu and Van Staden, 2003
Malawi	Roots	Water	*In vitro* human sperm motility parameters	An increase in the total spermatozoa motility	Lampiao et al., 2008
*Nigeria	Roots	Water	*In vitro* anti-sickling activity (using a plant mixture recipe containing 26 other plant species)	Mixture exhibited significant (63.4% inhibition) activity on sodium metabisulphite induced sickling effect	Egunyomi et al., 2009
South Africa	Roots	Hexane, ethanol, water	*In vitro* antibacterial activity using the disc-diffusion and microdilution assays	No antibacterial activity were detected against the four bacteria strains tested	McGaw et al., 2000
South Africa	Roots	Water	*In vitro* anti-schistosomiasis activity	After 1 h, 50 mg/ml water extract effectively killed the schistosomula	Sparg et al., 2000
South Africa	Leaves	Ethanol	*In vitro* antidepressant activity via the serotonin reuptake transport (SERT) assay	Isolation of (−)-loliolide with IC_{50} value of 977 μM	Neergaard et al., 2010
South Africa	Leaves	Methanol, water	*In vitro* antiepileptic and anticonvulsant $GABA_A$-benzodiazepine receptor binding assay	Moderate dose-dependent antiepileptic and anticonvulsant effect	Risa et al., 2004
South Africa	Leaves	Ethanol	*In vitro* selective serotonin reuptake inhibitor (SSRI) activity	Noteworthy *in vitro* affinity for the SSRI binding site exhibiting with an IC_{50} value of 0.4 mg/ml	Pedersen et al., 2006
South Africa	Leaves	Ethanol	Antidepressant activity via *in vitro* [affinity to the SERT and for inhibitory effects on the SERT, the noradrenalin transporter (NAT) and the dopamine transporter (DAT)].and *in vivo* [tail suspension test (TST) and forced swim test (FST), locomotor activity] assays	Ethanol extract exhibited significant antidepressant-like effects in FST assay	Pedersen et al., 2008
South Africa	Leaves	70% ethanol, water	*In vitro* antidepressant activity using SERT protein binding assay	70% ethanol extract had moderate inhibitory effect on neuronal uptake of serotonin	Nielsen et al., 2004
South Africa	Flowers	70% ethanol, water	*In vitro* antidepressant activity using SERT protein binding assay	Ethanol extract had moderate inhibitory effect on neuronal uptake of serotonin	Nielsen et al., 2004
*Zimbabwe	Roots	Ethanol	*In vivo* aphrodisiac activity (extract used as a formulation: *Mondia whitei*+*Ekerbegia capensis*)	Formulation showed a dose-dependent direct affect in increasing sexual arousability, better sexual stimulation and increase in copulatory efficiency in rats	Gundidza et al., 2009

* = Indicates studies where *M. whitei* was investigated as a formulation or in combination with other plant species.

Table 2
Physicochemical characteristics of dried roots of *Mondia whitei*.

Physicochemical parameters	Quantity (mg)/100 g dry matter
Water content	98.0±0.80
Ash matter	7950.0±50.00
Proteins	9882.0±8.00
Total sugar	53670.0±174.00
Lipid matter	2950.0±50.00
Total reducing power (vitamin C equivalent)	0.966±10.2800
Phenolic compounds	24.202±0.1060
Selenium	0.0108±0.0040
Calcium	1071.56±8.800
Magnesium	2217.54±3.170
Iron	9.82±0.920
Sodium	17.62±0.180
Copper	1.47±0.050

Adapted from Youkeu (2008).

extracts on the endurance of rats subjected to intense physical activity was performed. The author discovered that rats fed with meal supplemented with 0.61% *M. whitei* were better adapted to the physical effort with a performance difference of approximately 6% with respect to the control group.

3.3. Other traditional and general uses

The woody middle part of thicker roots is used as a toothbrush. In folk medicine; the Luhya community of western Kenya chew the roots for good luck before setting out to perform a difficult task, as a cure for bewitchment, as a love potion, to overcome hang-overs, a symbol of peace and a sign of power (Mukonyi, 2002). In the past, the seeds were apparently used as a potent arrow poison during hunting (Hutchings et al., 1996). In South Africa, the stems are well beaten to yield long and shiny strands tough enough to be used for the making of ropes (Crouch et al., 1998a). As the brightly coloured flowers are very attractive (Fig. 1C), it is highly recommended for cultivation as a garden plant thereby adding to its horticultural potential. It is a vigorous, fast-growing plant which makes it ideal to cover trellises (Ross, 1978). Based on the sweet vanilla-like flavour, Van Wyk and Gericke (2000) predicted that *M. whitei* has the potential to be a novel African fragrance or spice. Similarly, Crouch et al. (1998a) highlighted that the missionary, Father Gerstner, described the taste of the roots as first bitter then afterward sweet. This is reminiscent of vanilla, ginger, marzipan, cinnamon and liquorice (Crouch et al., 1998a). Therefore, the aromatic roots of *M. whitei* could become a useful food-flavouring agent.

Table 3
Physicochemical and nutritional analysis of the roots and leaves of *Mondia whitei*.

Parameters	Quantity (mg/g)	
	Roots	Leaves
Potassium	11.34	32.05
Sodium	5.61	24
Magnesium	1.40	2.83
Calcium	3.08	8.25
Iron	0.20	0.43
Zinc	0.03	0.07
Copper	0.003	0.06
Manganese	0.64	0.05
Cadmium and lead	Trace	Trace
Crude protein	4.35	21.8
Beta carotene	0.004	0.022
Thiamine	0.78	3.70
Niacin	0.52	8.15
Riboflavin	0.62	2.45
Fructose	0.008	0.015
Xylose	9.17	18.70
Glucose	2.40	9.0

Adapted from: www.infonet-biovision.org-mondia.

4. Chemical and phytochemical studies

4.1. Compounds isolated from M. whitei

Despite its long use, only a few studies exist on the isolation of bioactive compounds from *M. whitei*. The most common and well-known compound isolated from *M. whitei* is 2-hydroxy-4-methoxybenzaldehyde (5) which is a potent tyrosinase inhibitor (Kubo and Kinst-Hori, 1999). The compound has also been isolated from *M. whitei* by earlier researchers as highlighted by Koorbanally et al. (2000). In addition, the authors reported for the first time, the isolation of isovanillin (6), previously thought to be synthetic from *M. whitei*. Subsequently, the first report of the isolation of coumarins and coumarinolignan as well as chlorinated coumarinolignan from the genus *Mondia* was reported (Patnam et al. 2005). Recently, bioassay guided isolation led to the isolation of (−)-loliolide (4), which showed affinity to SERT in a binding assay (Neergaard et al., 2010). The structures of some compounds (1–6) that have been isolated from *M. whitei* are depicted in Fig. 2. A number of other compounds have also been isolated from *M. whitei* as stated by other authors (Koorbanally et al., 2000; Patnam et al., 2005). Relative to the high number of uses in traditional medicine as well as the published articles on the preliminary screening of the crude extracts, the number of isolated compounds is rather small. Particularly, investigations on *M. whitei* as an aphrodisiac have been extensive yet; the compound(s) responsible for the observed effects, both *in vitro* and *in vivo*, remain to be isolated. This leaves us with the challenge to conduct more stringent research to isolate and identify more novel bioactive compound(s) from this species.

4.2. Phytochemical studies of M. whitei

A recent qualitative phytochemical analysis of ethanol extract of *M. whitei* indicated the presence of reducing sugars and triterpenes, however, other essential phytochemical groups such as alkaloids, flavonoids, phenolics and saponins were not detected (Quasie et al., 2010). Subsequently, Abdou Bouba et al. (2010) reported the presence of phenolics (6.40 g GAE/100 g DW), flavonoids (2.99 g/100 g DW) and tannins (0.073 g/100 g DW) in this species. The authors further reported antioxidant activity of the extract via its high hydroxyl radical scavenging activity. Etoundi et al. (2010) detected a phenolic

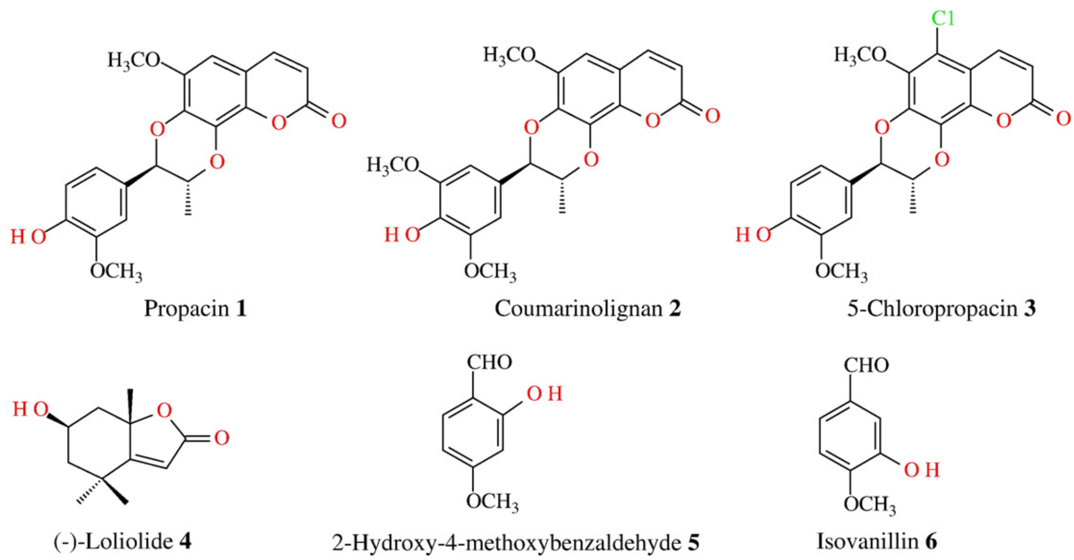

Fig. 2. Chemical structures of some compounds isolated from *Mondia whitei*.

content of 4.32 mg/g of catechin equivalent in *M. whitei* extracts. Some scholars have suggested that the presence of a wide range of plant secondary metabolites such as phenolics, flavonoids and tannins in plants have a direct correlation to the exhibited biological activities. Ndhlala et al. (2010a) for instance, attributed antioxidant bioactivity to the presence of phenolics in the plant. Hence, these plant secondary metabolites detected in *M. whitei* could have partially contributed to some of the observed bioactivities. An investigation of the physico-chemical characteristics of *M. whitei* has also been reported (Youkeu, 2008). Based on the results outlined in Tables 2 and 3, *M. whitei* can easily serve as essential mineral and vitamin supplements. However, there are high levels of disparities in some of the parameters (for example, values for calcium, magnesium) reported in Tables 2 and 3 and this remains a major concern. There are a number of attributing factors such as collection localities, seasonal variation effects and method of analysis which could explain the observed disparities. More studies are strongly recommended taking these factors into account as well as using more sensitive equipment.

5. Conservation strategies for *M. whitei*

Okigbo et al. (2008) defined conservation as "a process involved in the preservation and careful management of the environment as well as natural resources to prevent neglect, over-exploitation and destruction". Globally, most natural resources especially medicinal plants are under strain due to increasing urbanisation and increased demand by the population (Okigbo et al., 2008; Zschocke et al., 2000). This high demand has led to indiscriminate harvesting and over-exploitation of the natural flora within all ecosystems (Cunningham, 1997). In South Africa, the problem of medicinal plant over-exploitation is not a recent one. As early as 1946, Father Jacob Gerstner, a Zululand missionary, predicted the looming extinctions of 'doomed' plant species used for traditional medicine (Gerstner, 1946). In particular, Jäger and Van Staden (2000) identified the increased use of the non-renewable plant materials such as roots, bulbs and bark as the major contributing factor in the decline of most species in the wild.

M. whitei is a slow-growing plant that takes about 15 years to attain a tuber of sufficient size for consumption (McGeoch, 2004). The ecological implications of intense harvesting of such a slow-growing plant to satisfy the ever increasing demand are that harvesting from the wild is unsustainable and the species may become threatened. Indeed, the plant is reported to be scarce and difficult to locate in the wild (Nichols, 2005). Around 1898, local extermination of *M. whitei* had been recorded in the Durban area of South Africa due to collection of its roots (Crouch et al., 1998a). In the past, *M. whitei* was protected by conservation strategies such as traditional seasonal restriction on harvesting the species and taboo against the gathering of traditional medicines by menstruating women. Nevertheless, as a result of the cultural change, increased entry of more amateur gatherers into the medicinal plant trade due to rising unemployment levels, these ancient controls are rapidly breaking down (Cunningham, 1993). According to the Southern African red data list, *M. whitei* used to be listed as a vulnerable species (Victor, 2002) however, it has now been elevated to endangered status (Red List of South African Plants, 2009). Further evidence of the threats to *M. whitei* was reported by Ndawonde et al. (2007), who listed the species as one of the nine species that is scarce and threatened in Zululand (KwaZulu-Natal Province, South Africa). In East Africa, McGeoch (2004) also reported that *M. whitei* has been classified as an endangered species requiring immediate protection from extinction due to over-exploitation.

Generally, South Africa has a low success rate in the use of law enforcement for biodiversity conservation (Wiersum et al., 2006). Therefore, a new approach that involves the stimulation of medicinal plant cultivation has been recommended (Van Staden, 1999; Wiersum et al., 2006). The domestication of medicinal plants will create new opportunities such as alternative/additional sources of income and help reduce the pressure on the wild natural medicinal plant population (Jäger and Van Staden, 2000). Ndawonde et al. (2007) identified *M. whitei* as a popular plant species that can be easily propagated in South African communal gardens to counter the problem of extinction. This was demonstrated by using seeds, which easily germinate after two weeks. Alternatively, tip cuttings can also be used for propagation (Crouch et al., 1998b). Generally, community based medicinal plant farming coupled with the provision of subsidy and training in basic effective propagation techniques would enhance conservation of medicinal plants. A model example of this was implemented in India where Giridhar et al. (2005) used triacontanol soil drenching to increase the plant growth and yield of tubers, with enhanced flavour content, of *Decalepis hamiltonii* Wight & Arn. plantlets. The authors developed a micropropagation protocol used to produce a large number of good plantlets which were given to the tribal people in the hill region, providing them with both food and medicine.

Another approach is the use of plant part substitution as a means for sustainable harvesting. Several workers have recommended that the non-destructive medicinal plant part particularly the leaves should be investigated for possible bioactivity (Zschocke et al., 2000). Aremu et al. (2010) for instance, reported a better anthelmintic activity in *Cyathea dregei* leaf extracts than in the root which is frequently used in traditional medicine. As evidenced in this review (Fig. 3), most of the studies on *M. whitei* have focused on the root/root bark extracts which is an indication of the high stress on the underground plant part. Zschocke and Van Staden (2000) also suggested that traditional healers should be encouraged to use related plant species where similar biological activity has been demonstrated. The use of the exotic *Cinnamomum zeylanicum* to replace *M. whitei* for example, has long been suggested by Cunningham (1988). Therefore, it is necessary to investigate a possible replacement species for similar biological activities which *M. whitei* has exhibited.

Furthermore, South African scientists have attempted to overcome the challenges of possible extinction of *M. whitei*

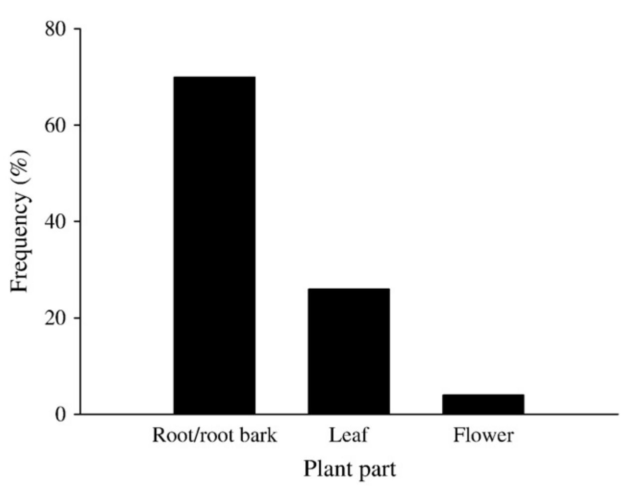

Fig. 3. The frequency of the various organ parts used in the investigation of *Mondia whitei* efficacy in published papers.

through the use of biotechnological techniques. Tissue culture regenerated plantlets are ideal for mass propagation of many species such as *M. whitei* due to the numerous advantages associated with *in vitro* techniques. Using the micropropagation technique, an estimated 2000 plantlets could be produced from a single seed after 7–8 subculture cycles at 4–6 week intervals. Subsequently, these plantlets were easily rooted after 3 months (McCartan and Crouch, 1998). Zobolo et al. (2009) also successfully rooted *M. whitei* shoot cuttings in naphthalene acetic acid (NAA) of varying concentrations. It was observed that shoot cuttings cultured in 0.5 mg/l NAA were significantly higher ($p < 0.05$) in terms of the number of roots as well as the root length. Nevertheless, the use of new and more potent plant growth hormones such as the *meta*-topolins to enhance the efficiency of the micropropagation protocols is pertinent (Werbrouck, 2010). Presently, we are investigating the effects of the *meta*-topolins as well as the application of hairy root culture in *M. whitei* to maximise the production of the main secondary metabolite, 2-hydroxy-4-methoxybenzaldehyde. Generally, hairy root cultures are characterised by high biosynthetic capacity and genetic fidelity as well as biochemical stability (Toivonen, 1993). Although more expensive compared to chemical synthesis, hairy root culture in *M. whitei* serve as a natural source and may offer an alternative prospect for the investigation of biosynthetic pathways and commercial production of secondary metabolites such as 2-hydroxy-4-methoxybenzaldehyde.

6. Economic status and commercial prospects of *M. whitei*

6.1. Economic status of *M. whitei*

Approximately 80% of the population in Asian and African countries depend on traditional medicine for primary healthcare (WHO, 2008). In the last two decades, the developed and developing countries have witnessed a significant rise in the demand for herbal medicines with global sales estimated at US$ 60 billion (Hoareau and DaSilva, 1999). This is evidenced in the expansion of scientific research relating to traditional medicine and transnational markets for traditional medicinal products. The trade of medicinal plants is increasing locally, regionally and internationally (Marshall, 1998).

In most countries where *M. whitei* occurs, there is no detailed data on the harvest and trade of the species. A recent rapid appraisal, however, indicated that the species wholesales for between US$ 0.20–0.30/kg and retails at more than US$ 2/kg. In Kenya, fresh roots were sold for US$ 7–12/kg (Mukonyi et al., 2002). *M. whitei* collected by gatherers from natural forests can generate an estimated US$ 3600 per year (McGeoch et al., 2008). In Uganda, the average price per piece (0.01–0.02 m in diameter and 0.3–0.4 m in length) or kg of roots increases from the collectors (US$ 0.60/kg), middlemen (US$ 1.20/kg) and finally to the retailers (US$ 1.50/kg) (Agea et al., 2008). To the best of our knowledge in South Africa however, there is no available published data on the average price for *M. whitei*. Therefore, the contribution of this species to socio-economic livelihoods especially in South Africa requires investigation.

6.2. Commercial prospects of M. whitei

In South Africa, Mander et al. (1996) identified the lack of understanding with respect to the cultivation and economics of producing useful indigenous plants especially the medicinal species as one of the most limiting factors in their commercialisation. The authors observed that the producers do not engage in commercialisation because there is no indication of the potential profit from producing plants for local and international markets. In KwaZulu-Natal, however, commercialisation of indigenous plants seems to be well developed in the informal sector, with a large and active trade all year round (Mander, 1998). Makunga et al. (2008) also acknowledged that the informal sector was generally well-established but still remained an '*underground economy*'. The authors highlighted and strongly recommended the need to explore the untapped potentials of the formal medicinal sector. For *M. whitei,* most of the available studies and literature focuses on the pharmacology, taxonomy and nutritional aspects only. In Kenya, a *Mondia* tonic® (rich in vitamins and essential elements) has been registered as a food supplement with the Kenya Bureau of Standards, and with the Kenya Industrial Property Institute (Mukonyi et al., 2002). In contrast with modest commercialisation of *M. whitei* in Kenya, the commercial potentials of *M. whitei* in South Africa have remained unexploited even for medicinal purposes. Evidence suggests that the demand for traditional medicines continues to grow in South Africa (Makunga et al., 2008). This has been attributed to the growing human population, the low employment growth rate, the influx of foreigners seeking work, and the limited resources of the government to service primary health care. In addition, the strong cultural attachment by many communities to traditional practices, even within modernised urban settings, sustains the demand for traditional plant products (Mander et al., 1996; Mander et al., 2007). Despite the high utilisation of the species in South Africa, the lack of commercialisation of the species is worrisome and remain a major question that deserve more stringent studies.

6.2.1. Potential in pharmaceutical and nutraceutical industries

As evidenced in this review, the number of studies on *M. whitei* efficacy against various ailments is increasing. Diseases such as erectile dysfunction, epilepsy, depression, inflammation and microbial infection are of great concern worldwide. Erectile dysfunction which has remained rampant among men aged 40–70 years is the inability to achieve and maintain an erection sufficient to permit satisfactory sexual intercourse because of some physiological and psychological factors (Lue, 2000; Martey and He, 2010). Using various approaches and assay techniques (Table 1), different researchers have investigated the efficacy of *M. whitei* on erectile dysfunctions. Most of the authors observed that extracts from *M. whitei* have a significant positive aphrodisiac effect on sexual drive thereby attenuating erectile dysfunction. Watcho et al. (2007b) for instance, reported that the root extracts caused an increase in mount, intromission and erectile frequencies of inexperienced male rats. Although the majority of the investigation of aphrodisiac activity of *M. whitei* is credited to the Watcho's group, other research groups have also been involved in recent times (Gundidza et al., 2009; Quasie et al., 2010). Besides the aphrodisiac activities, there have also been numerous studies on the efficacy of *M. whitei* on diseases such as epilepsy, depression and mental disorders. According to WHO (2011), an estimated 50 million people worldwide have epilepsy, with almost 90% of these people being in developing countries. *M. whitei* extracts has exhibited noteworthy effects on these diseases as reported in many published articles (Nielsen et al., 2004; Pedersen et al., 2006) and more active research is on-going. Tyrosinase is postulated to play a role in the formation of neuromelanin in the human brain and could be essential to dopamine neurotoxicity in addition to contributing to the neurodegeneration associated with Parkinson's disease (Nihei et al., 2004). However, it has been observed that 2-hydroxy-4-methoxybenzaldehyde is a potent tyrosinase inhibitor; therefore, *M. whitei* has the potential to combat the above mentioned problem owing to the inhibitory compound present in the species.

The efficacy of *M. whitei* against microbial and helminth infections has been studied (Matu and Van Staden, 2003; Sparg et al., 2000). Most of the published results especially the antibacterial activities (Table 1) were not promising, however Sparg et al. (2000) observed a moderate anti-schistosomiasis activity of the water extract (roots). Hence, we suggest the need for further investigation of antimicrobial efficacy of *M. whitei* on other microbial strains as *M. whitei* is widely used against microbial related ailments.

The use of *M. whitei* against most of these devastating diseases coupled with the active research serves as potential ethnopharmacological leads to the discovery of novel and more efficient therapeutics. Considering the number of studies on *M. whitei*, the possibility of discovering new compound(s), which would be of high therapeutic value, cannot be overlooked. In event of such a discovery, it will lead to more interest from large pharmaceutical companies, both local and international, with the sole purpose of accessing large volumes of plant material. In terms of the nutritional potentials, *M. whitei* could serve as another natural source of essential mineral and vitamin supplements. Similarly, Youkeu (2008) suggested the utilisation of *M. whitei* as an alternative food supplement to enhance the performance of sportsmen and women without the fear of a ban associated with drug doping.

6.2.2. Potential in cosmeceutical and agricultural industries

The enzyme tyrosinase is responsible for melanisation in animals and regulates melanogenesis in mammals. Abnormal melanin pigmentation such as freckles and melasma are considered by humans to not be aesthetically pleasing. However, these problems can be partially suppressed by deactivating tyrosinase. As various papers suggest that *M. whitei* contains tyrosinase inhibitor, there is great potential for it in the cosmetic industry. The importance of this unusual phenolic compound, 2-hydroxy-4-methoxybenzaldehyde has been emphasised, characterised and quantified in *Hemidesmus indicus* (L.) Schult. (Sircar et al., 2007). Furthermore, the insecticidal activity of the compound was investigated using the roots of *D. hamiltonii* and it was demonstrated against three coleopteran stored product pests (George et al., 1999). The authors reported potent insecticidal activity and encouraged its use because of the simplicity of its application, retention of viability of seeds and the low toxicity. Both *D. hamiltonii* and *M. whitei* contain 2-hydroxy-4-methoxybenzaldehyde, which indicates that *M. whitei* could be used as an insecticide. Interestingly, these two species (*H. indicus* and *D. hamiltonii*) have a number of similarities with *M. whitei* in addition to being a member of the same sub-family Peroplocoideae. Hence, the chances of successful application of similar techniques and derived use from the two species are high with *M. whitei*.

7. Concluding remarks

M. whitei is a popular medicinal plant in traditional medicine hence; scientists have investigated the extracts for activities such as aphrodisiac, antidepressant, anti-inflammatory, antibacterial and antiepileptic. However, most of the studies focused on the aphrodisiac activity efficacy (Table 1). To a certain extent, the traditional uses of *M. whitei* have been validated as shown in the interesting results from the various *in vitro* and *in vivo* studies examined in this review. The various pharmacological activities evident in the studies provide scientific support for the wide usages in traditional medicine. The favourable results also serve as an indication of the great economic potential of *M. whitei* in view of the possibility of isolation of novel compounds. Nevertheless, more intensive phytochemical studies, especially on bioactivity guided isolation of the new compounds would enhance the economic potential of *M. whitei*.

Mutagenic and toxic effects of *M. whitei* have not really received enough attention, only a few preliminary reports of its safety exist (Watcho et al., 2001). In terms of toxicity, most plant species used in traditional medicine are generally assumed to have low toxicity due to their long-term consumption by humans and animals (Luseba et al., 2007; Verschaeve and Van Staden, 2008). *M. whitei* has a long history of traditional use, with no reports of any serious side effects, suggesting that the species can be considered as generally safe. Recent investigations, however, have revealed that many plants used as food, medicine or herbal concoction do have mutagenic or toxic effects when examined in more detail (Fennell et al., 2004; Ndhlala et al., 2010b). Therefore, both preliminary and exhaustive toxicology tests/adverse effects of *M. whitei* are still pertinent because most of the available safety evaluations remain inadequate and inconclusive.

In addition, the monitoring and follow-up in cases of perceived over-exploitation of vulnerable species such as *M. whitei* are rare. Some long-standing proposals for sustaining the industry that include encouraging domestication, providing incentives for sustainable harvesting as well as monitoring and enforcing the law which to date have been made without much result (Mander et al., 1996). *M. whitei* is an example of a typical African species with the aforementioned neglects. The species is very useful and is becoming rare in the wild with fear of extinction in time. Therefore, this review highlighted the valuable, untapped potential as well as possible conservation strategies of the species. For instance, there is need to strengthen ancient cultural practices that ensure sustainable management, key community members such as the headmen, traditional community leaders and traditional community police officers could be vital in the enforcement of laws against indiscriminate harvesting of the species (Hamilton, 2004). Furthermore, rigorous studies to evaluate possibilities of sustainable harvesting of this species from the wild have been recommended (Lamidi and Bourobou Bourobou, 2010). In order to meet the escalating demand for *M. whitei* especially with the possibility of its commercialisation in South Africa, there would be a need to stimulate the small and medium scale cultivation of this species in regions that support its good growth. From a plant biotechnologist point of view, tissue culture techniques remain an ideal process for the mass micropropagation of *M. whitei*. In addition, a more stringent investigation to increase the production of the essential secondary metabolites via hairy root culture is worth pursuing. A comprehensive comparative analysis of secondary metabolite yields as well as the pharmacology of the resultant hairy roots will be highly valuable data for commercial purpose (Nigro et al., 2004). The promising economic potential of *M. whitei* with the possibility of the development of a commercial product will greatly benefit the indigenous people and the South African economy. There will be an increase in demand by both the local and international markets leading to the commercial cultivation of the plant not only in South Africa, but also in neighbouring countries. Furthermore, it will generate additional income in terms of patent rights for the people who have been the custodians of the indigenous knowledge. Lastly, the attractive nature of the *M. whitei* flowers makes it a species with horticultural potential in both local and overseas markets; however it remains an attractive area to be fully considered and exploited by researchers.

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