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Review Article

BALANITES MAUGHAMII SPRAGUE (*ZYGOPHYLLACEAE*) IN TROPICAL AFRICA: A SYNTHESIS AND REVIEW OF ITS CHEMISTRY, PHARMACOLOGY, AND MEDICINAL POTENTIAL

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ABSTRACT

Balanites maughamii is an important medicinal plant species in Southern Africa. This study is aimed at providing a critical review of the biological activities, phytochemistry, and medicinal uses of *B. maughamii.* Documented information on biological activities, medicinal uses, and phytochemistry of *B. maughamii* was collected from several online sources which included BMC, Scopus, SciFinder, Google Scholar, Science Direct, Elsevier, PubMed, and Web of Science. Additional information on the biological activities, phytochemistry and medicinal uses of *B. maughamii* were collected from pre-electronic sources such as book chapters, books, journal articles, theses, and scientific publications sourced from the university library. This study showed that the bark, fruits, leaves, and roots of *B. maughamii* are traditionally used for magical purposes, as emetic, tonic, fish poison, insecticidal, and herbal medicine for bilharzia. Phytochemical compounds identified from the bark, fruits, and leaves of *B. maughamii* are aliphatic alcohols, aliphatic ketones, benzenoid compounds, aliphatic acids, amino acids, coumarin, aliphatic esters, flavonoids, aliphatic aldehydes, and sterol. Pharmacological research revealed that *B. maughamii* extracts have adulticidal, antibacterial, antiplasmodial, bitterness, molluscicidal, and mutagenic activities. Future research should focus on evaluating the phytochemical, pharmacological, and toxicological properties of *B. maughamii* crude extracts as well as compounds isolated from the species.

Keywords: *Balanites maughamii*, Ethnopharmacology, Herbal medicine, Indigenous pharmacopeia, Southern Africa, *Zygophyllaceae*.

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INTRODUCTION

Balanites maughamii Sprague is a member of the *Zygophyllaceae* family. The *Zygophyllaceae* family is a heterogeneous family consisting of about 23 genera and 235 to 240 species in the dry regions of Africa, America, Australia, Asia, and Europe [1]. Delimitation of taxa within the *Zygophyllaceae* family has repeatedly changed over time. For example, the genus *Balanites* Delile has been assigned its own family *Balanitaceae* due to unique morphological and anatomical characteristics [2-4]. However, other researchers, for example, Cronquist [5], Fahn *et al.* [6], and Narayana *et al.* [7] included the genus *Balanites* in *Zygophyllaceae* family. Evaluation of phylogenetic relationships within the *Zygophyllaceae* family based on DNA sequences of non-coding trnL-F and plastid gene rbcL region support assignment of the genus *Balanites* in the *Zygophyllaceae* family [1,8-11]. The genus name *"Balanites"* was derived from a Greek word which means "acorn-shaped" in reference to the fruits of the genus [12,13]. The species name *"maughamii"* is in honor of Mr. Maugham, the former British Consul at Lourenco Marques (now Maputo in Mozambique) who collected the type specimen of the species in Southern Mozambique [13-16]. The synonym of *B. maughamii* is *B. dawei* Sprague [17]. The English common names of the species "torchwood," "torch fruit tree," and "y-thorned torchwood" are in reference to the dry kernels of the species which have traditionally been burnt as torches [13,14,16-19]. *B. maughamii* is one of the valuable medicinal plant species in South Africa, and the species is included in the book "medicinal plants of South Africa," a photographic guide to the most commonly used herbal medicines in the country, including its botany, major medicinal applications active phytochemical compounds [20]. According to Van Wyk and Gericke [21] and Van Wyk *et al.* [20], *B. maughamii* is considered an important tonic in Southern Africa. Due to the popularity of *B. maughamii* as traditional medicine, the bark of the species is marketed as a traditional medicine in the traditional medicine informal markets in Gauteng, KwaZulu-Natal, and Mpumalanga Provinces in South Africa [22-31]. *B. maughamii* is also categorized as declining in KwaZulu-Natal Province [22], and research by Mander [32] ranked the species thirteenth out of 70 most widely demanded herbal medicine by consumers in the province. Similarly, Twine [33] ranked *B. maughamii* as third out of 36 tree species harvested for their bark in Southern Maputaland in KwaZulu-Natal Province, South Africa. Based on these reports, it is clear that *B. maughamii* has an enormous contribution to primary health care of local people in many areas of South Africa. Several people in developing countries depend on medicinal plants such as *B. maughamii* for their primary health care needs [34,35]. Therefore, this review is aimed at providing a comprehensive appraisal of the biological activities, phytochemistry, and medicinal uses of *B. maughamii* crude extracts.

BOTANICAL DESCRIPTION OF *B. MAUGHAMII*

B. maughamii is a medium-sized deciduous or semi-deciduous tree reaching 20–25 m in height [17,19]. *B. maughamii* has a spreading crown, branching at about 2 m above the ground level [14] with a straight, deeply folded, fluted, and buttressed trunk which is up to 30 cm or more in diameter [17]. The bark is smooth, yellowish brown, mottled, or gray in color and becoming roughly fissured in larger and older specimens [14,18]. The branches are usually yellow to grayish-green in color, covered with short grayish-green hairs when young but becoming smooth with age, characterized by strong, robust, sharp conspicuous forked spines on the upper bole and branches as well as the younger stems. The leaves are compound made up of two leaflets on very short furry stalks, alternate and arranged spirally, with triangular stipules [14,17,18]. The leaflets are ovate to almost round in shape, acute or shortly acuminate, entire margins, dark gray-green in color, with velvet hairs when young and these persisting on the under-surface to maturity [18]. The flowers are small, inconspicuous, borne in small bunches, yellowish green in color, sessile or with short peduncle, petals with dense hairs on the outer surface [14,18]. The fruit is a one-seeded drupe, oblong-ellipsoid in shape, depressed at both ends and reddish brown in color at ripening [19]. The skin of the fruit is firm but thin, eventually brittle, containing spongy and fibrous, dark and oily mesocarp and a stone with thick endocarp [14,17-19].

B. maughamii is subdivided into two subspecies, subsp. *maughamii* and subsp. *acuta* Sands which are distinguished mainly by leaflet shape and pubescence. The leaflets on fertile shoots of subsp. *maughamii* are rounded or obtuse in shape and are pubescent, while those of subsp. acuta are acute to shortly acuminate and glabrous. The subsp. *maughamii* is widespread in distribution and has been recorded in Zimbabwe, Kenya, Mozambique, Malawi, South Africa, Zambia, and Swaziland [16-19,36-44]. The subsp. maughamii has been recorded in clay-loam, fine clay silt and sandy soil in sand forest, dry open woodland, bushland, seasonally waterlogged flood-plains, along river banks, near springs, around pans, dunes, sandstone outcrops, and termitaria at an altitude ranging from sea level to 1000 m above sea level [14,17-19,40]. The subsp. *acuta* has been recorded in Southeast Kenya and Northeast Tanzania in alkaline soil and light sandy soil on coral rag or lava in mixed coastal, lowland evergreen rainforest, ground-water forest, coastal thicket, and riverine thicker at an altitude ranging from sea level to 500 m above sea level [17]. However, most ethnobotanical and ethnopharmacological literature do not separate *B. maughamii* into specific subspecies, but rather *B. maughamii sensu lato,* and this is the approach that has been adopted in the current review.

The fruits of *B. maughamii* which have a pleasant sweet scent and taste, but later become bitter are edible in Southern Africa mainly as a snack [14,18,45-52]. According to Mahlo [53], the fruits of *B. maughamii* are used in South Africa as additives in the production of sweets and alcoholic beverages. The kernels of *B. maughamii* yield large quantities (about 60%) of tasteless, odorless, clear and yellow edible oil that burns well and have good lubricative qualities and used as a massage oil [14,19,38,45,48,54,55]. Research by Grace and Sands [19] showed that oil pressed from the seed kernels of *B. maughamii* is used in the Limpopo Province in South Africa as a dressing for hides and skins. Since the oil from *B. maughamii* kernels is flammable, it is, therefore, suitable for industrial use [19].

MEDICINAL USES OF *B. MAUGHAMII*

The bark, fruits, leaves, and roots of *B. maughamii* are used for various traditional and medicinal applications (Table 1). *B. maughamii* is mainly used for magical purposes (good luck, wards off evil spirits, bath said to be stimulating, and exhilarating), as emetic, tonic, fish poison, insecticidal, and herbal medicine for bilharzia (Table 1 and Figure 1). Other minor medicinal applications recorded in a single country include use of the species as arrow poison, mosquito repellent, snail poison, purgative and panacea, and as herbal medicine for cough, malaria and nervous complaints [19-21,55-62]. In Mozambique, the bark of *B. maughamii* is mixed with Phaseolus vulgaris L. as an herbal medicine for hematuria [21]. In South Africa, the leaves of *B. maughamii* are used as ethnoveterinary medicine for diarrhea in cattle [53,63,64].

PHYTOCHEMICAL AND NUTRITIONAL COMPOSITION OF *B. MAUGHAMII*

Very little attention has been paid to the macro- and micro-elements of *B. maughamii.* One report done by Dierenfeld *et al.* [78] partly studied this subject and reported values of the nutritional composition of leaves and twigs of *B. maughamii* (Table 2). Langlois [66] identified the compounds scopoletin and stigmasterol from the ethanol bark extract of *B. maughamii* while Olivier [55] identified alcohol precipitable solids and flavonoids from the bark extracts of the species (Table 3). The major aliphatic acids and aliphatic alcohols exceeding 10.0% identified from the fruits of *B. maughamii* include hexanal (14.0%), isovaleric acid (15.7%), and hexanoic acid (40.4%) [79,80]. Major amino acids exceeding 10.0 mg/g of dry weight identified from the bark and leaves of *B. maughamii* include alanine, alloisoleucine, aspartic acid, tryptophan, glutamic acid, glycine, isoleucine, phenylalanine, lysine, proline, leucine, serine, histidine, threonine, glutamine, tyrosine, asparagine, and valine [55]. Future research should focus on evaluating the biological activities of the isolated compounds.

BIOLOGICAL ACTIVITIES OF *B. MAUGHAMII*

The following biological activities have been reported from the bark, fruit, leaf, and twig extracts of *B. maughamii:* Adulticidal [60,81], antibacterial [53,82], antiplasmodial [67], bitterness [83], molluscicidal [84-86], and mutagenic [87,88] activities.

Adulticidal activities

Mavundza [60] and Mavundza *et al*. [81] evaluated the adulticidal activities of dichloromethane and ethanol bark extracts of *B. maughamii* against *Anopheles arabiensis* mosquitoes. Both dichloromethane and ethanol extracts exhibited activities with 55% and 65% mosquito mortality, respectively [60,81].

Antibacterial activities

Mahlo [53] and Mahlo and Chauke [53,82] evaluated antibacterial activities of acetone leaf extracts of *B. maughamii* against *Bacillus cereus, Pseudomonas aeruginosa, Escherichia coli,* and *Enterococcus faecalis* using agar-dilution and serial dilution methods with tetracycline as a positive control. The minimum inhibitory concentration (MIC) values of extracts without polyethylene glycol (PEG) ranged from 0.2 mg/ml to 1.6 mg/ml while the addition of PEG resulted in a reduction of antibacterial activities with MIC values ranging from 3.1 mg/ml to 12.5 mg/ml [53,82].

Table 1: Medicinal applications of *Balanites maughamii*

Medicinal use	Parts of the plant used	Country	References
Arrow poison	Fruit	South Africa	[19,55]
Bilharzia	Bark	South Africa and Swaziland	[15,49,65]
Cough	Fruits	South Africa	[20,55,56,58,60-62]
Emetic	Bark	South Africa and Swaziland	[14,15,17,18,20,21,45,49, 55,60,66-69]
Fish poison	Stem bark	Malawi and Zimbabwe	[17,19,38,70]
Hematuria	Bark mixed with *Phaseolus vulgaris* L.	Mozambique	[21]
Malaria	Roots	Mozambique	[55,59]
Insecticidal	Barks	South Africa and Swaziland	[49,60,71,72]
Magical purposes (good luck, wards off evil spirits, bath said to be stimulating and exhilarating)	Bark, fruits, and roots	Mozambique, South Africa, and Swaziland	[14,15,18,20-22,24,28,48, 49,53,57,66,68,69,73-77]
Nervous complaints	Bark	South Africa	[55]
Panacea	Bark and fruits	Mozambique	[21,57]
Purgative	Bark and roots	South Africa	[19]
Snail poison	Fruit	South Africa	[55]
Tonic	Bark and fruits	Mozambique and South Africa	[20,21,57]
Ethnoveterinary medicine	-	-	
Diarrhea in cattle	Leaves	South Africa	[53,63,64]

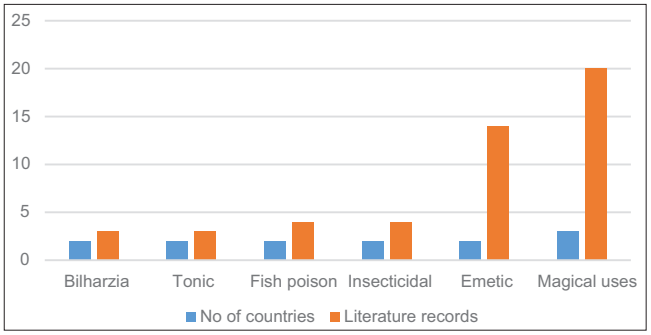

Fig. 1: Traditional and medicinal applications of *Balanites maughamii*

Table 2: Nutritional composition of *Balanites maughamii* leaves and twigs after Dierenfeld *et al*. [78]

Nutritional composition	Values
Acid detergent bound protein (% dry matter)	1.9
Acid detergent fiber (% dry matter)	40.4
Ash (% dry matter)	7.4
Calcium (% dry matter)	0.8
Copper (% dry matter)	3.5
Crude protein (% dry matter)	21.8
Iron (% dry matter)	150.0
Neutral detergent fiber (% dry matter)	64.5
Magnesium (% dry matter)	0.4
Manganese (% dry matter)	17.7
Phosphorus (% dry matter)	0.2
Potassium (% dry matter)	1.8
Sodium (% dry matter)	0.03
Sulfuric acid lignin (% dry matter)	13.9
α-tocopherols (µg/g dry matter)	7.3
γ-tocopherols (µg/g dry matter)	8.0
δ-tocopherols (µg/g dry matter)	3.0
Vitamin E (IU/kg dry matter)	11.8
Water (%)	68.1
Zinc (% dry matter)	10.8

Antiplasmodial activities

Prozesky *et al.* [67] evaluated the antiplasmodial activities of dichloromethane stem bark extracts of *B. maughamii* against *Plasmodium falciparum* by means of the flow cytometric test. The extract exhibited activities with half maximal inhibitory concentration value of 1.9 µg/ml [67].

Bitterness activities

Olivier and Van Wyk [83] evaluated the bitterness values of the bark of B. maughamii using procedures prescribed by the World Health Organization [89] and the European Pharmacopoeia [90] and compared the bitterness value of quinine hydrochloride set at 200 000. The bitterness value of 4211±2019 was obtained for B. maughamii bark. The physiological effects associated with the bitter taste of herbal medicines are ascribed to the bitter tonic (amarum) effect, that is, result in the stimulation, secretion of saliva, secretion of gastric juices, and secretion of bile through taste stimuli through the nervus vagus [83].

Molluscicidal activities

Research by Wager [84] revealed that the fruits of *B. maughamii* that fell in infested water were observed to inhibit proliferation of snails and cercariae. Pretorius *et al.* [85] evaluated the molluscicidal properties of the kernel and pulp of ripe fruits of *B. maughamii.* The extracts were toxic to snails at concentrations of 25 mg/ml, and molluscicidal activities were retained in powdered material for up to 122 days, but leaves and seeds showed no molluscicidal properties [85]. Ojewole [86] evaluated molluscicidal activities of the bark, fruit, and leaf extracts of *B. maughamii* by exposing adult *Bulinus africanus* and *Biomphalaria pfeifferi* to sublethal and lethal doses of crude and aqueous bark, leaf, and twig extracts of the species for a period of 24 h using niclosamide (Bayluscide®) (Coating Place Inc., Washington DC, WA, US) as reference molluscicide for comparison. The extracts demonstrated moderate to strong molluscicidal activity with lethal dose 90% value of 50 ppm–100 ppm compared to the positive control, niclosamide (Bayluscide®) which killed all the snails at a dose of 1 ppm [86].

Mutagenic activities

Elgorashi *et al.* [87] evaluated the mutagenic activities of dichloromethane and 90% methanol bark extracts of *B. maughamii* using the Ames test, micronucleus test, comet assay, and VITOTOX®

Table 3: Phytochemical composition of *Balanites maughamii*

Phytochemical composition	Values	Parts	References
Aliphatic acid			
Butanoic acid (%)	0.4	Fruits	[79,80]
Heptanoic acid (%)	0.3	Fruits	[79,80]
2-Heptenoic acid (%)	0.1	Fruits	[79,80]
n-Hexadecanoic acid (%)	0.2	Fruits	[79,80]
Hexanoic acid (%)	40.4	Fruits	[79,80]
(*E*)-3-Hexenoic acid (%)	1.4	Fruits	[79,80]
Isovaleric acid (%)	15.7	Fruits	[79,80]
4-Methylpentanoic acid (%)	0.02	Fruits	[79,80]
Nonanoic acid (%)	0.1	Fruits	[79,80]
Octadecanoic acid (%)	0.02	Fruits	[79,80]
(*Z*)-9-Octadecenoic acid (%)	0.01	Fruits	[79,80]
Octanoic acid (%)	0.3	Fruits	[79,80]
(*Z*)-2-Octenoic acid (%)	0.01	Fruits	[79,80]
Pentadecanoic acid (%)	0.01	Fruits	[79,80]
Tetradecanoic acid (%)	0.01	Fruits	[79,80]
Valeric acid (%)	0.9	Fruits	[79,80]
Aliphatic alcohol			
Oct-1-en-3-ol (%)	3.9	Fruits	[79,80]
(*E*)-Oct-2-en-1-ol (%)	0.2	Fruits	[79,80]
Octan-1-ol (%)	2.0	Fruits	[79,80]
Aliphatic aldehyde			
(*Z*)-4-Decenal (%)	0.2	Fruits	[79,80]
Hexanal (%)	14.0	Fruits	[79,80]
Nonanal (%)	8.4	Fruits	[79,80]
Octanal (%)	1.9	Fruits	[79,80]

(contd...)

Table 3: ***(continued)***

Phytochemical composition	Values	Parts	References
Aliphatic ester			
Butyl hexanoate (%)	0.2	Fruits	[79,80]
n-Butyl hexadecanoate (%)	0.01	Fruits	[79,80]
Ethyl caproate (%)	2.3	Fruits	[79,80]
Methyl caproate (%)	3.0	Fruits	[79,80]
Propyl hexanoate (%)	0.05	Fruits	[79,80]
Aliphatic ketone			
Nonan-2-one (%)	0.5	Fruits	[79,80]
Octan-3-one (%)	0.5	Fruits	[79,80]
(*E*)-3-Octen-2-one (%)	1.0	Fruits	[79,80]
3,4-Epoxy-2-octanone (%)	0.4	Fruits	[79,80]
Benzenoid compound			
Methyl salicylate (%)	0.01	Fruits	[79,80]
Miscellaneous cyclic compounds			
γ-n-Amylbutyrolactone(%)	0.02	Fruits	[79,80]
Bicyclo[3.3.1]nonane-2,7-dione (%)	0.05	Fruits	[79,80]
δ-Caprolactone(%)	0.6	Fruits	[79,80]
τ-Caprolactone (%)	0.6	Fruits	[79,80]
Dimethylmaleic acid anhydride (%)	0.05	Fruits	[79,80]
Dimethyl trisulfide(%)	0.2	Fruits	[79,80]
γ-Ethoxy-butyrolactone(%)	0.04	Fruits	[79,80]
5-Ethyl-2 (5H)-furanone(%)	0.03	Fruits	[79,80]
1-(2-Methyl-1-cyclopenten-1-yl)-ethanone (%)	0.01	Fruits	[79,80]
S-Methyl methanethiosulfonate(%)	0.01	Fruits	[79,80]
Amino acid			
Alanine (mg/g dry weight)	40.6–158.0	Bark and leaves	[55]
Alloisoleucine (mg/g dry weight)	33.8–40.1	Bark and leaves	[55]
α-aminoadipic acid (mg/g dry weight)	3.7–5.9	Bark and leaves	[55]
α-aminobutyric acid (mg/g dry weight)	0.4–0.8	Bark and leaves	[55]
γ-aminobutyric acid (mg/g dry weight)	0.4–9.3	Bark and leaves	[55]
β-aminoisobutyric acid (mg/g dry weight)	4.1–5.0	Bark and leaves	[55]
Asparagine (mg/g dry weight)	38.1	Bark and leaves	[55]
Aspartic acid (mg/g dry weight)	56.7–308.1	Bark and leaves	[55]
Cysteine (mg/g dry weight)	9.4	Bark and leaves	[55]
Glutamic acid (mg/g dry weight)	61.4–84.4	Bark and leaves	[55]
Glutamine (mg/g dry weight)	18.5	Bark and leaves	[55]
Glycine (mg/g dry weight)	2.7–10.0	Bark and leaves	[55]
Histidine (mg/g dry weight)	12.5	Bark and leaves	[55]
Isoleucine (mg/g dry weight)	22.4–33.5	Bark and leaves	[55]
Leucine (mg/g dry weight)	29.2	Bark and leaves	[55]
Lysine (mg/g dry weight)	11.5–21.1	Bark and leaves	[55]
Methionine (mg/g dry weight)	2.6–3.0	Bark and leaves	[55]
Ornithine (mg/g dry weight)	9.7	Bark and leaves	[55]
Phenylalanine (mg/g dry weight)	18.0–32.2	Bark and leaves	[55]
Proline (mg/g dry weight)	32.6–99.1	Bark and leaves	[55]
Serine (mg/g dry weight)	13.1–26.7	Bark and leaves	[55]
Threonine (mg/g dry weight)	12.9	Bark and leaves	[55]
Tryptophan (mg/g dry weight)	12.3–14.2	Bark and leaves	[55]
Tyrosine (mg/g dry weight)	15.7–29.3	Bark and leaves	[55]
Valine (mg/g dry weight)	32.9–51.7	Bark and leaves	[55]

test. All the extracts showed mutagenicity or DNA damage and chromosomal aberrations in at least one test [87]. Similarly, Taylor *et al.,* [88] evaluated the genotoxic activities of dichloromethane and 90% methanol leaf extracts of B. maughamii in human peripheral blood lymphocytes using the micronucleus test. The leaf extract showed positive results in all micronucleus tests, while the twig extract was positive in micronucleus and Comet tests without S9 (human white blood cells *in vitro*) [88].

CONCLUSION

The present review summarizes the ethnomedicinal uses, phytochemistry and biological activities of the bark, fruit, leaf, and twig extracts of *B. maughamii*. In the past 80 years, *B. maughamii* has been the subject of pharmacological research, focusing on the molluscicidal activities of the species. Early research revealed that the fruits of *B. maughamii* are lethal to freshwater snails and other organisms that transmit the parasitic dimorphic *Schistosoma* trematode worms which cause schistosomiasis also known as bilharzia. From a chemical, pharmacological and toxicological point of view, *B. maughamii* has not received any major emphasis. At present, there is not yet enough data on ethnopharmacological evaluations on the species that can be correlated with its medicinal applications. Therefore, detailed phytochemical, pharmacological, and toxicological studies of B. maughamii are recommended.

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AUTHOR'S CONTRIBUTIONS

The author declares that this work was done by the author named in this article.

CONFLICTS OF INTEREST

The author declares that they have no conflicts of interest.

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