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 heterogenous 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 [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 Gerke [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 fissed, 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 well as the younger stems. The leaves are compound made up of two leaflets on very short furry stalks, alternate and arranged spirally, with...
**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 | [14,15,17,18,20,21,45,49,55,56,60-69] |
| 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               | Bark                                  | South Africa and Swaziland | [49,60,71,72] |
| Magical purposes (good luck, | Bark, fruits, and roots               | Mozambique, South Africa, and Swaziland | [14,15,18,20,22,24,28,48,49,53,55,67,69,73-77] |
| wards off evil spirits, bath said to be stimulating and exhilarating) | | | |
| Nervous complaints         | Bark                                  | South Africa             | [55]       |
| Panacea                    | Bark and fruits                       | Mozambique               | [21,57]    |
| Purgative                  | Bark and roots                        | South Africa             | [19]       |
| Snail poison               | Fruit                                 | Mozambique               | [55]       |
| Tonic                      | Bark and fruits                       | Mozambique and South Africa | [20,51,57] |
| Ethnoveterinary medicine   | Leaves                                | -                        | [53,63,64] |
| Diarrhea in cattle         |                                       | South Africa             | [53,63,64] |

*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, 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 1,000 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 stigmasteryl 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, alloselieucine, aspartic acid, tryptophan, glutamic acid, glycine, isoelucine, 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*: Adulcidical [60,81], antibacterial [53,82], antiplasmodial [67], bitterness [83], molluscicidal [84-86], and mutagenic [87,88] activities.

**Adulcidical activities**

Mavundza [60] and Mavundza et al. [81] evaluated the adulcidical 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].
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 421 ± 19 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].

## Molluscidal 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 molluscidal activities were retained in powdered material for up to 122 days, but leaves and seeds showed no molluscidal 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 molluscidal 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. [67] evaluated the mutagenic activities of dichloromethane and 90% methanol bark extracts of *B. maughamii* using the Ames test, micronucleus test, comet assay, and VITOTOX®

![Fig. 1: Traditional and medicinal applications of *Balanites maughamii*](image_url)

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 |

Table 3: Phytochemical composition of *Balanites maughamii*

| Phytochemical composition | Values | Parts | References |
|---------------------------|--------|-------|------------|
| Aliphatic acid | | Fruits | [79,80] |
| Butanoic acid (%) | 0.4 | Fruits | [79,80] |
| Heptanoic acid (%) | 0.3 | Fruits | [79,80] |
| 2-Heptanoic acid (%) | 0.1 | Fruits | [79,80] |
| n-Hexadecanoic acid (%) | 0.2 | Fruits | [79,80] |
| Hexanoic acid (%) | 40.4 | Fruits | [79,80] |
| (Z)-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 | | Fruits | [79,80] |
| Oct-1-en-3-ol (%) | 3.9 | Fruits | [79,80] |
| (Z)-Oct-2-en-1-ol (%) | 0.2 | Fruits | [79,80] |
| Octan-1-ol (%) | 2.0 | Fruits | [79,80] |
| Aliphatic aldehyde | | Fruits | [79,80] |
| (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...)
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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