Background

Balanites aegyptiaca., also known as 'Desert date' in English, a member of the family Zygophyllaceae, is one of the most common but neglected wild plant species of the dry land areas of Africa and South Asia. This tree is native to much of Africa and parts of the Middle East. In India, it is particularly found in Rajasthan, Gujarat, Madhya Pradesh, and Deccan. This is one of the most common trees in Senegal. It can be found in many kinds of habitat, tolerating a wide variety of soil types, from sand to heavy clay, and climatic moisture levels.

Botanical description

This species grows as a multibranched, spiny shrub or tree reaching up to 10 m in height. It develops a spherical crown composed of one or several distinct masses. The trunk remains short and often branches near the base. The bark appears dark brown to grey and shows deep fissures. Branches bear stout yellow or green thorns up to 8 cm long. The leaves consist of two separate leaflets; the leaflets are obovate, asymmetric, 2.5-6 cm long, bright green, and leathery, with fine hairs present at the young stage. The plant produces fragrant, yellowish-green flowers in fascicles within the leaf axils.

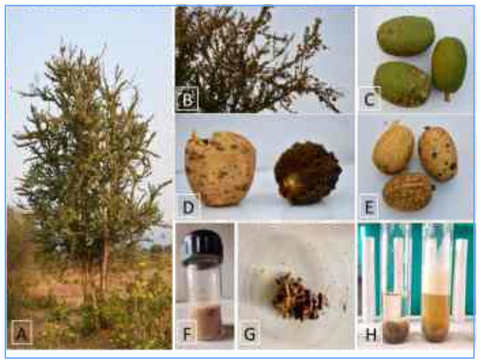

Figure 1: Morphology of *Balanites aegyptiaca*: (A) habit, (B) leaves, (C) Unripe fruit, (D) rind (left) and pulp (right), (E) ripened fruits, (F) Powder of Mesocarp, (G) mesocarp after drying and (H) Foam formed after shaking mesocarp in water

The plant bears a long, narrow drupe measuring 2.5-7 cm in length and 1.5-4 cm in diameter. Immature fruits appear green and tomentose, while mature fruits turn yellow and glabrous. The pulp tastes bitter-sweet and remains edible. The seed forms a hard pyrene (stone), measuring 1.5-3 cm in length; it is light brown, fibrous, and extremely hard, accounting for 50-60 % of the fruit weight. One kilogram contains approximately 500-1,500 dry, clean seeds.

The tree produces small, inconspicuous, hermaphroditic flowers that insects pollinate. Birds and animals disperse the seeds through ingestion. The species begins flowering and fruiting at 5-7 years of age, and trees achieve maximum seed production between 15 and 25 years.

Although cultivation and naturalization obscure its original range, the species is believed to be indigenous to dry regions south of the Sahara, extending to Malawi in the Rift Valley and the Arabian Peninsula. Humans introduced it into cultivation in India and Latin America. The species exhibits broad ecological adaptability but mainly grows on level alluvial sites with deep sandy loam soils and reliable water access. After the seedling stage, it does not tolerate shade and regenerates naturally in open woodland or savannah. It thrives as a lowland species up to 1,000 m altitude, preferring mean annual temperatures of 20-30 ° C and 200 annual rainfalls between 250 and 400 mm.

Figure 2: *Balanites aegyptiaca* Seeds of different size

Traditional Uses

People widely use different parts of this plant in traditional medicine. The fruit extract shows spermicidal activity without causing vaginal irritation, and its effect increases with concentration. Long-term use of fruit pulp extract has caused testicular dysfunction in animal studies. People use the fruits to treat whooping cough, skin diseases, dysentery, constipation, liver disorders, and jaundice, and they also consume them as a laxative and purgative. In some regions, children suck the fruits as a confectionery.

The seeds serve as expectorant, febrifuge, anthelmintic, antibacterial, and antifungal agents. Seed oil is applied to wounds and tumors, and ground seeds are used to treat colic and impaction in livestock. The bark acts as a spasmolytic and is used to treat syphilis, roundworm infections, malaria, and as a fish poison. People use root extracts for abdominal pain, malaria, purgation, and as an emetic; roots are also used in folk remedies for contraception. The leaves help clean infected wounds, and aqueous leaf extracts show antibacterial activity. In several African countries, people burn twigs to repel insects and use bark in soap making. Overall, traditional systems across Africa and Asia use this plant for digestive disorders, infections, parasitic diseases, jaundice, wound healing, contraception, and malaria.

Phytochemical constituents

Balanites aegyptiaca produces a wide variety of secondary metabolites, including polyphenols (phenolic acids, flavonoids, and coumarins), alkaloids, steroids, saponins (spirostanol saponins, furostanol saponins, and open-chain steroidal saponins), and pregnane glycosides. These compounds have been isolated from different plant tissues such as fruits, seeds, leaves, stem bark, roots, and galls.

Polyphenols exhibit characteristic phenolic structural features, containing one or more aromatic rings with one or more hydroxyl groups. Polyphenols are classified into phenolic acids, flavonoids, stilbenes, lignans, and tannins. These compounds play an important role as natural therapeutic agents and help prevent degenerative diseases, particularly cancer, cardiovascular diseases, and neurodegenerative disorders.

Phenolic acids are non-flavonoid polyphenolic compounds derived from benzoic acid and cinnamic acid. Major phenolic acids isolated from different tissues of *Balanites aegyptiaca* include caffeic acid, ferulic acid, gentisic acid, *p*-coumaric acid, sinapic acid, syringic acid, vanillic acid, 2-methoxy-4-vinylphenol, 2,6-dimethoxyphenol, 2-methoxy-3-(2-propenyl)-phenol, 2-methoxy-4-(1-propenyl)-phenol.

Flavonoids possess a diphenylpropane (C6-C3-C6) flavone skeleton with a three-carbon bridge between two phenyl rings, usually cyclized with oxygen. Flavonoids isolated from different tissues of *B. aegyptiaca* include kaempferol, myricetin, quercetin, isorhamnetin, hyperoside, quercitrin, quercetin-3-glucoside, quercetin-3-rutinoside, isorhamnetin-3-O-glucoside, isorhamnetin-3-rutinoside, isorhamnetin-3,7-diglucoside, isorhamnetin-3-O-robinobioside. Coumarins are phenolic compounds characterized by fused benzene and α-pyrone rings. They exhibit anti-inflammatory, anticoagulant, antimicrobial, anticancer, antioxidant, and neuroprotective activities. Bergapten and marmesin are coumarins isolated from the stem bark of *B. aegyptiaca*.

Alkaloids are nitrogen-containing compounds that show diverse biological activities and are particularly important in cancer treatment. Alkaloids identified from the stem bark and fruits of *B. aegyptiaca* include N -trans-feruloyltyramine, N-cis-feruloyltyramine, and trigonelline.

Phytosterols are naturally occurring bioactive compounds with chemical structures like cholesterol. Clinical studies show that dietary intake of phytosterols such as β-sitosterol, campesterol, and stigmasterol significantly reduces low-density lipoprotein levels in humans. Steroids isolated from *B. aegyptiaca* include diosgenin, 6-methyldiosgenin, yamogenin, cholesterol, β-sitosterol, campesterol, stigmasterol, and rotenone.

Saponins are bioorganic compounds with triterpenoid or steroidal skeletons that are glycosylated with different sugar moieties at various positions. Steroidal saponins are classified into spirostanol, furostanol, and open-chain steroidal saponins. These compounds exhibit a wide range of biological activities, including hemolytic, anti-inflammatory, antimicrobial, insecticidal, anticancer, and molluscicidal properties. Various spirostanol, furostanol, and open-chain steroidal saponins have been isolated from the fruits, seeds, roots, and stem bark of *B. aegyptiaca*.

Pharmacological activity

The biochemical activities attributed to *B. aegyptiaca* encompass a

Figure 3: Major phytochemical constituents isolated from *Balanites aegyptiaca*, including polyphenols (phenolic acids, flavonoids, and coumarins), alkaloids, phytosterols, and steroidal saponins. These bioactive compounds contribute to the plant's wide range of pharmacological and therapeutic properties.

wide array of therapeutic potentials, including anti-tumor, anti-hepatitis, antioxidant, antibacterial, antidiabetic, wound healing, anti-inflammatory, anti-parasite, anticonvulsant, antiplasmodial, anti- larvicidal, and molluscicidal properties. These diverse actions high light the plant's significant potential as a medicinal agent, owing to its rich repertoire of naturally occurring active ingredients. Additionally, *B. aegyptiaca* has been utilized as a fumigant to aid in the healing of circumcision wounds. Notably, methanolic ex tracts derived from the stem bark of *B. aegyptiaca* have demonstrated antiangiogenic, antiproliferative, and anticancer properties. However, the yield of these phytomolecules was found to be very low. Therefore, most of the phytocompounds were screened for their bioactivities initially by in vitro assays. Further, it was interesting to identify the possible mode of action of the potent phytocompounds.

Its fruit, seed, flower, bark, and leaf extracts show strong antioxidant activity by scavenging free radicals through mechanisms such as hydrogen atom transfer, electron donation, and metal chelation, largely due to their high phenolic and flavonoid content. Methanolic and ethanolic extracts demonstrate particularly strong DPPH radical scavenging and β-carotene bleaching inhibition, with activities comparable to or exceeding common antioxidants such as green tea and spinach. The plant also shows anticancer potential, as compounds like balanitoside effectively inhibit Ehrlich's ascites carcinoma in vivo. Rich phytochemical diversity, including flavonoids, tannins, saponins, alkaloids, and terpenoids, contributes to its antimicrobial activity, offering promise against drug-resistant pathogens. Ethanolic bark extracts exhibit significant hepatoprotective effects, restoring liver enzyme levels and histological structure in chemically induced hepatitis models. The aqueous fruit mesocarp extract displays notable antidiabetic activity by reducing plasma glucose levels, supporting its traditional use in diabetes management. Additionally, fruit pulp extracts provide neuroprotective effects, improving memory and acetylcholine balance in experimental models of Alzheimer's-like cognitive impairment through antioxidant and acetylcholinesterase inhibition. The plant also promotes wound healing, as leaf, root, and methanolic extracts enhance wound contraction, collagen formation, tensile strength, and hydroxyproline content. Overall, these findings highlight *B. aegyptiaca* as a promising source of bioactive compounds for nutraceutical, pharmaceutical, and therapeutic applications.

Figure 4: Common multi-target biological activities of Balanites aegyptiaca. The plant exhibits diverse pharmacological properties including antidiabetic, anticancer, antimicrobial, antioxidant, wound healing, antimalarial, and neuroprotective (anti-Alzheimer's) effects, highlighting its broad therapeutic potential.

B. aegyptiaca is a highly valuable yet underutilized dryland tree species possessing remarkable ecological adaptability and extensive ethnomedicinal importance. The plant is rich in diverse phytochemicals, including polyphenols, flavonoids, saponins, alkaloids, phytosterols, and steroidal compounds, which contribute to its wide spectrum of pharmacological activities. Scientific studies validate many of its traditional uses, demonstrating antioxidant, antidiabetic, hepatoprotective, antimicrobial, anti-inflammatory, anticancer, wound healing, and neuroprotective properties. The presence of bioactive compounds such as diosgenin, β-sitosterol, quercetin, δ-cadinene, and various steroidal saponins highlights its significant potential in nutraceutical, pharmaceutical, and therapeutic industries. Given its resilience to arid conditions and multipurpose utility ranging from traditional medicine and food to biopesticidal and molluscicidal applications *B. aegyptiaca* represents a promising species for sustainable dryland development. However, despite its immense medicinal and economic value, it remains largely neglected and underexploited.

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Desert Date

(*Balanites aegyptiaca*)

Phytochemicals, Traditional Uses & Health Benefits

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