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Review paper

Exploring the Silviculture and Silvics of Desert Date (*Balanites aegyptiaca*) in Northern Nigeria: Opportunities for Economic, Social and Environmental Development

Mohammed Inusa Nguru[1], Ali Bulama[2]*, Rabiu Sabo[1], and Mustapha, A.U.[1]

[1,3,4]School of Sciences, Department of Science Laboratory Technology, Mai Idris Alooma Polytechnic Geidam, Yobe State, Nigeria.
[2]Department of Forestry and Wildlife Management, Federal University Gashua, Yobe State, Nigeria.
*Corresponding Author E-mail: alibulama7@gmail.com

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ABSTRACT: One of the most prevalent yet underappreciated wild plant species in the dry regions of Nigeria and all of Africa is the desert date (*Balanites aegyptiaca*). Its many uses, such as a source of food, fuel, wood, oils, household items, animal feed, and numerous pharmacological applications, are extremely obvious. Several *Balanites* preparations have been shown to have antifeedant, larvicidal, antidiabetic, molluscicide, anthelminthic, and contraceptive effects. This review paper emphasized the need of investigating the potentials of the *Balanites aegyptiaca* tree as an economic tree under sound management practices in northern Nigeria's drier regions. Also, an attempt was made to investigate the silviculture and silvics chosen for the species as done in several sections of the species' geographical range. *Balanites* was discovered to be one of the species chosen for the restoration of the Sahelian environment as part of the Pan-African reforestation project, the Great Green Wall for the Sahara and Sahel initiative (GGW). Local and empirical knowledge of the species should form the foundation for future study in the characterization of suitable agro-forestry systems, genetic enhancement of the species, and Invitro cultivation of the vegetative part to increase seed and seedling output.

Keywords: *Balanites aegyptiaca*, Conservation, Food Security, Livelihood improvement, Silviculture and Silvics

INTRODUCTION

Nigeria has the largest economy in Africa, with $514.05 billion in GDP (Business Day, 2022). Despite this rating, over 80 million Nigerians are categorized as poor, with more than half of them being multidimensional poor due to insufficient access to education, health, energy, and other basic amenities (Poverty Environmental Action, 2021).In Nigeria, the poverty rate is rising (Akinyetun et. al., 2021). Even though Northern Nigeria has a wide fertile terrain for cultivating a variety of agricultural commodities and many trees of economic, social, and environmental importance, the level of poverty there is rising at an extremely worrisome rate (Jaiyeola and Choga, 2020).Similarly, Jigawa, Kebbi, and Gombe were the top three poorest states in Nigeria despite the region's abundance of fertile land, and eight of the top ten (10) poorest states in Nigeria were located in the Northern region, where 87% of the population survives on less than US$1 per day (NBS, 2022). In addition, desert is encroaching at a rate of 0.6 km per year in most of these Northern Nigerian states (Ibrahim et al., 2022).

Most alarmingly, despite the nation's standing as sixth in the world for oil and gas production, more than 60% of the population still uses fuel wood (firewood) as a source of energy for cooking and heating that is primarily supplied from the remaining degraded forested areas (Furo, 2014; Ali et al., 2022). This might be in part because local native tree species' silvics are not well understood.One of the indigenous tree species cut down indiscriminately by locals is *Balanites aegyptiaca* (National Academies, 2008; Ali et al., 2022). In Northern Nigeria*, Balanites aegyptiaca* is one of the most commonly used tree species for fuelwood. It also provides commercial quantities of edible fruits, gum Arabic, and medicinal herbs. It also contributes significantly to biodiversity preservation (Kamal et al., 2019).Drought-resistant species such as *Balanites aegyptiaca*, *Zizyphus mauritiana,* and *Piliostigma reticulatum* were considered as the top three forest trees most heavily relied upon by the local population as a means of livelihood in rural areas in a study to determine the forest productivity in northern Nigeria (Aduradola, 2012).

Natural forests in arid locations are under increasing strain due to the world's rapid population growth and climate change, which includes Nigeria (Kamal et. al., 2019). This issue necessitates the planting of multipurpose trees resistant to harsh environments, and *Balanites aegyptiaca* has been identified as one of these tolerant tree species (Onefeli and Adesoye, 2014; Toit and Malherbe, 2017).Nigeria's northern regions are known for their dry environment, and overgrazing, urbanization, development, and growth of agriculture all put strain on the country's natural forests (Adeniran and Daramola, 2018).With highly adaptable tree species like *Balanites aegyptiaca,* intensive farm forestry and agroforestry have the potential to supplement the current supply of forest products and services, reverse the negative effects of climate change, enhance biodiversity, and provide other environmental services (Gunter et. al., 2011). Despite its numerous contributions (medicinal, fruit and gum production fodder, firewood, shelterbelt tree, carbon sequestration, habitat for many birds and insects), and potential, *Balanites aegyptiaca* is regarded as one of the most neglected forest tree species of Africa and South Asia (Chothani and Vaghasiya, 2011; Elmugheira, 2021). *Balanites*' information is rarely, if ever, incorporated in text books recommended for teaching and learning in schools (National Academies, 2008). There is little information available on the silvic and Silviculture of the *Balanites aegyptiaca* species.

Moussa (2020), for example, investigated the value chain of *Balanites aegyptiaca*'s fruits, among others, and examined the Silviculture and socioeconomic elements of fruit exploitation in the Maradi region of Niger Republic's southern section. As a result, little is known about the Silviculture or horticultural sciences of tree species in Nigeria, particularly in the country's northern region. Against this backdrop, the researchers investigate the silviculture and silvics of an important Sahel multifunctional tree species.

METHODOLOGY

This research is a review study in which 71 literature from 120 downloaded literatures obtainedthrough Goggle Web, Goggle Scholars, and Web of Science were selected andreviewed.The criteria used for the searching and selection include the followings words and phrases: *Balanites aegyptiaca*, Desert date, Threaten trees of the desert, threatened trees of the Sahara, Threatened trees in Northern Nigeria**,** Silviculture of *Balanites*, Silvic of *Balanites*, livelihood improvement roles of *Balanites*, environmental roles of *Balanites*, morphological characteristics of *Balanites*, chemical characteristics of*Balanites*. The 71 reviewed literature comprised 27 literature published between 2018 to 2022; 26 literature published between 2012 and 2017, 10 published works within 2006 and 2011, Five (5) literatures published between 1999 and 2005;One (1) literature published within the years of 1993 and 1998 and Two (2) published articles between 1988 and 1992 (Appendix 1). There were 39 literatures that are broad or global context, Six (6) focused on Africa, 15 were focused on Nigeria, Five (5) focused on Sudan, , Three (3) were associated toNiger Republic, Two (2) literature on arid zone/Sahel, and One (1) literature each connected to Washington D.C., Uganda, Cameronand Denmark. Moreover, 48 of the reviewed literature were directly focused on Desert date (*Balanites aegyptiaca),* Seven (7) on Poverty alleviation and Livelihood; Three (3) literature each on Tropical trees and Silviculture; Two (2) literature each on Medicinal Plants and Fuelwood; and One (1) literature each on Food and Evolution; Wild plants, Desertification; Forest management; African lost Crops ;and Indigenous Trees (Appendix 1). Furthermore, a total of 60Journal articles, 10 scientific reports, Two (2) Theses, Two (2) E-books, and One (1) Leaflet were reviewed (Appendix 1). The authors of the reviewed literatures adopted different methodology comprising 37 experimental work, Twenty Six (26) reviewed works; Six (6) qualitative studies, and Four (4) of the authors adopted mixed methodology (Appendix 1).

OVERVIEW OF THE CHARACTERISTICS OF DESERT DATE (*BALANITES AEGYPTIACA)* TREE SPECIES

Distribution of the *Balanites aegyptiaca* tree species

Balanites aegyptiaca is also known as Desert date. It is an evergreen xerophytic tree of Sudano-Sahelian region

of Africa's native (Ndoye et al., 2004) as well as the Middle East and South Asia (Hassan et al., 2016). It inhabit the drier parts of India particularly Gujarat, Madhya Pradesh and Rajasthan **(**Murthy et. al., 2021). *Balanites aegyptiaca* has the widest natural distribution in African drier lands (Kobbail, Abaker, Salih, and Abdallah.2020**)**. It's said to have originated from tropical Africa. There are about twenty five (25) known species distributed from tropical Africa to Burma **(**Aliero and Bunza, 2016). Evidence of earlier association of the tree species with man have been found in the grave of a Neanderthal man buried 60,000 years ago (Henry. Brooks, and Piperno. 2014).

The earliest known medical document is a 4000-year old Sumerian clay tablet, which among others, recorded *Balanites aegyptiaca* as remedies for various illnesses by the time of the ancient Egyptian civilization **(**Saboo et al., 2014). *Balanites aegyptiaca* thrives well in arid, semiarid, sub humid tropical savannahs, hot dry areas, along water courses, in woodlands as well as in low lands and on river banks in depressions, and on the slopes of rocky hills (Kobbail, Abaker, Salih, and Abdallah.2020)**.**

Morphology of *Balanites aegyptiaca*

Balanites aegyptiaca is characterized by long, straight, green spines arranged spirally along the branches; each spine has a two-leaflet compound leave below it(National Academies, 2008). The tree is a slow growing, and growth rate ranges between 1-5 m/years. Therefore, considered slow growing trees with an average maturity yield of 100-150 kg of ripe fruits/year. It is an evergreen or semi-deciduous and multi branched, and can grow up to 10m or taller.

The mature *Balanites aegyptiaca* trees may live or exceed 100 years (Iwu, 2014). It flowers are small, inconspicuous, hermaphroditic and pollinated by insects(Joker, 2000; Ndoye et al., 2004).

Climatic and soil requirements

Balanites aegyptiaca requires a minimum rainfall of 200mm, a maximum rainfall of 800mm, and the maximum temperature of 40^0C (Yougouda et al., 2018). The tree can be found in many kinds of habitats, tolerate different climatic moisture levels from arid to sub-humid, as well as thrive in a variety of soil including sandy, loamy, clay and alluvial (Salami et al., 2019).Ahmed et al.(2017), found out that the best germination medium is sandy soil, while the best soil for seedling growth as sandy, clay and peat moss in the ratio of 1:1:1 (Iqbal, 2017; Joker, 2000**)**. *Balanites aegyptiaca* requires a minimum Altitude (m) of 300m and a maximum Altitude of 2000m. *Balanites aegyptiaca* is ecologically very flexible with excellent persistence (Mohamed and Bekhit, 2007).

Silviculture/ management practice

Silviculture originates from two Latin words: *Silva*, meaning forest; and *cultura*, meaning cultivation. It is therefore, the art and science of cultivating tree plantations, based on a sound knowledge of how tree grows (Ashton, 2000). Basically, silviculture can be defined as the scientific principles and techniques of controlling, protecting, and restoring the regeneration, composition, and growth of natural forest vegetation and its plantation analogs (Ashton, 2000).In its broadest sense it encompasses all procedures and activities that are carried out in the management of forest, Hence, it is an interplay between the needs of man and the conservation of forest resources (Gunter et al., 2011). Silvics is the study of the life history and general characteristics of forest trees and stands with particular reference to locality factors, as a basis for the practice of Silviculture (Ashton, 2000; Gunter et al., 2011).The Silviculture practices involve propagation, seed treatment, seedling management, planting types, growth factors, growth cycle, limitations to planting and management systems. Its foundation requires a good knowledge of vegetation autecology (silvics) which concerns the influences of various environmental factors on the growth and development of plants as individuals(Ashton, 2000). The plant faces multiple challenges including desertification and poor agricultural practice in Africa and Asia (Yougouda et al., 2018)

Propagation of *Balanites aegyptiaca*

Propagation by Seed

*Balanites aegyptiaca*tree can be propagated by seedlings after raising the seeds in the nursery and the germination length is 7 to 48 days(National Academies, 2008).Although, *Balanites aegyptiaca* is very slow growing at the seedlings stage, however the growth rate increases drastically at the saplings stage (Onefeli and Adesoye, 2014). The viability and germinability of the seeds are influenced by various factors such as physiological state, while germination is influence by scarification, acid and water treatments (Kamal et al., 2019). For example, soaking in Sulphuric acid for 1 hour or shallow nipping opposite the hilum side, at the narrow end of the seeds has been found to enhance germination (Omer, 2005). Seed viability is high and usually germinates to a potential of 80-85% without treatment but it takes a long time (6 weeks) or more (Mahgoub and Daffaalla, 1996). The slow growth rates reported for this species, necessitate the protection of the seedlings from weeds, fire, and cattle for at least 3 years (Kamal et al., 2019) *Balanites aegyptiaca* is dispersed by birds, humans, animals (e.g., sheep, goats, cattle and camels)

through their dungs after eating the fruits (Omer, 2005; Kamal et al., 2019). The fruit of *Balanites aegyptiaca* is indehiscent and edible, animals and birds including man lick the sticky mesocarp and throw the endocarp which passes through the digestive tract of animals' undigested (Mohammed et. al., 2010).

Vegetative propagation of *Balanites aegyptiaca*

Micro-propagation on *Balanites aegyptiaca* tree species exhibit a speedy means of raising clonal planting stock. This method is promising in obtaining regenerants and clonal multiplication for domestication of *Balanites aegyptiaca* (Mohamed and Bekhit, 2007).Vegetative regeneration such as air layering techniques has been reported in helping to allows the retention of genomic characteristics of species (Kamal et al., 2019). *Balanites aegyptiaca* can also be propagated by cuttings, potted stock or sucker. The tree species can also be propagated by vegetative parts such as root suckers, and stem cuttings in protected sites to avoid animals' browsing (Aduradola, 2012; Cecilia et al., 2019; Moussa et al., 2020). A thicker stems show better results than the thinner ones (Massaoudou et. al., 2022). While the characteristics slow nature of seed germination of *Balanites aegyptiaca*, there is a difficulty in regenerating the plant by seedling (Kamal et. al., 2019).Another promising result of *invitro* multiplication of *Balanites* was reported in many literature Ndoye et. al. (2003) used different growth hormones under different concentrations (IAA: Indole -3-acetic acid. IBA: Indole -3-butyric acid. NAA alpha-naphthalene acetic acid). While BAP (6-benzylaminopurine), Kin (6 –furfurylaminopurine), MS (Murashige and Skoog) medium were also reported as very effective means of propagating *Balanites aegyptiaca* tree species (Ndoye, 2003; Mohammed et al., 2010).

Result of the experiment using the hormone Indole -3-Butyric Acid (IBA) further showed that stem cuttings of *Balanites aegyptiaca* were capable of producing rooting (Mbah and Retallick, 1992). Another experiment was conducted by Mukhtar (2018) to show the effect of rooting media over the rooting of stem cutting of *Balanites aegyptiaca*, the rooting media (hormones) showed a statistical significance (0.05). However, stem cuttings can initiate rooting without the rooting media (Mukhtar, 2018).

A trial of Air layering was conducted by Kamal et al., (2019) to multiply *B. aegyptiaca* by vegetative means, in which in just two months, a very interesting result showed that *B. aegyptiaca*can be propagated by air layering without the use of rhizogenesis and sphagnum (hormones), and others that are beyond the farmers reach due to their high costs (Mbah and Retallick, 1992; Kamal et. al., 2019). It was reported that coppicing and pollarding *B. aegyptiaca* leads to fast regeneration after being lopped and heavily browsed. However, if the trees were grown for the purpose of fruiting, pollarding and coppicing are not employed or recommended (Orwa *et al.,* 2013). Some experiment conducted by Mbah and Retallick, (1992) revealed that stem cuttings of *Balanites aegyptiaca* are capable of profuse rooting and is in consonant with the result found by Ladipo (1980**)** in Nigeria, however, such result contended Kamal et al., (2019) that showed a total failure in India. Therefore, exploring these means of propagation of *Balanites aegyptiaca* species could help reduce the risk of it being endangered as documented previously, as well as reduce pressure on the natural forests thereby promoting conservation of trees and biodiversity, in addition to providing fuel wood and other products that support the livelihood of rural people (Naibbi, 2015; Ali et al., 2022).

Propagation by *In vitro* cultivation of *Balanites aegyptiaca*

Although *Balanites aegyptiaca* trees regenerate naturally by seed or after a moderate coppice, the tree species is endangered because of high rate of clearance for different purposes such as fuel wood, fodder, fruit, medicines, expansion of farmlands and urbanization (Elfeel, 2012; Naibbi, 2015; Ali et. al., 2022), therefore, the need to respond with a faster means of propagation of trees, rather than relying only on planting of seeds, coppicing and pollarding (Mohamed and Bekhit, 2007). Plant tissue culture (Invitro culturing) is an alternative and faster method of propagation and is being used widely for commercial propagation of a large number of plant species, including many medicinal plants **(**Mohamed and Bekhit, 2007). *Invitro* culturing of tree species offers a faster means of producing clonal planting stock for afforestation. The tissue culture of forest trees has shown a remarkable success in obtaining regenerants and clonal multiplication domestication of wild populations (Ndoye *et al.,* 2003**)**.

Procedures were developed for micropropagation of *Balanites aegyptiaca* causing axillary bud explants obtained from mature trees cultures were established in a medium supplemented with 2.5mg/l 6-benzylaminopurine (BAP) and 0.1 mg/l naphthalene acetic acid (NAA).Moreover, the effects of kinetin on shoot growth and proliferation in vitro was also investigated. Results show that shoots multiplication required 2.5mg/l of BAP, and the shoot length was found to have significantly affected by the presence of BAP or 6-furfurylaminopurine (Kin). Rooting of shoots In vitro was achieved on MS medium containing 20 mg/l of the auxin and indole butyric acid (IBA). Rooted shoots were successfully acclimated and transferred into soil, with 48% of the plantlets surviving (Ndoye et al., 2003). The same method was

repeated by Mohamed and Bekhit (2007), who used 6-benzyladenine (BA) instead of 6-benzyl aminopurine (BAP), which showed 90% survival percentage for adapted plantlet after 4 weeks as against 48% survival of previous finding by Ndoye et al., (2003). The plantlets were transferred to polythene bags and replanted successfully under field condition.

Diosgenin (steroidal sapogenin compound), which is a natural source of steroidal hormones is found in very few higher plant species including *Balanites*. In vitro production of natural diosgenin from callus cultures might be an alternative biotechnological approach to diosgenin production. The effects of growth regulators, explants, and somatic embryogenesis on sapogenin accumulation in *B. aegyptiaca* callus. The production of the sapogenin (diosgenin) by callus cultures of B. *aegyptiaca* has been described in details (Bishnu et al., 2006).

Seed treatment

Seeds are highly variable in weight and morphology depending on source. Seeds also defer in rate of germination. Fresh seeds can germinate without treatment. However, the seeds of *B. aegyptiaca* that passed through the intestinal tract of animals germinate well (Kamal et al., 2019). Soaking seed in hot water, cold water or boiling improve germination National Academies, 2008). Seed germination can be improved by immersing the seeds in boiling water for 7-10 minutes and then cool it slowly as demonstrated by many authors (Jøker, 2000; Eldin and Fadl, 2014).Seeds were treated with different mechanical and chemical methods, and growth hormones (Jøker, 2000; Ndoye et al., 2003; Bekhit, 2007; Eldin and Fadl, 2014).Seeds were treated with Conc. H_2SO_4, Conc. HCL and Conc. HNo_3, hot water treatment and then mechanical scraping method. However, seeds treated with acid concentration were found to have a higher rate of germination followed by hot water treatment (Gaisamudre and Sarwade, 2021). Contrary to the above findings, in Sudan El -Nour et al., (1991), found that boiling seeds in hot water reduce germination. Additionally, El-feel (2012), showed that soaking seed in cold water for 18 and 24 hours resulted in higher germination. Ahmed et al. (2017), find out that in Nine (9) pre-sowing treatments, the highest percent of germination comes from seeds soaked in water for 24 hours and least mean germination comes from seeds soaked in water for 15 minutes.

Economic, social and environmental roles of importance *Balanites aegyptiaca*

Balanites aegyptiaca is a multipurpose tree with high economic potential ranging from medicinal use, social and domestic uses (Okia et. al., 2013). Despite all the economic importance of the plant, the potential of *B. aegyptiaca* under management remains unexplored (Elmugheira, 2021). There is clear evidence of over exploitation of the specie in northern Nigeria for its multiplicity of uses ranging from use as food, medicine and other domestic uses.

Medicinal uses

B. aegyptiaca tree has a medicinal value in Africa and Asia. Different parts of the plant are used for the medication of different ailments such as liver and spleen problems, epilepsy and yellow fever (Nadro and Samson, 2014). From a very long time *B. aegyptiaca* has been noted for its curative properties to several diseases as a home remedy (Al-thobaiti and Zeid, 2018). For example, the fruits have been used in the treatment of liver and spleen diseases. The fruit is also known to kill the snails which carry schistosomiasis and bilharzia flukes. A pharmagnostic and quality characterization of *Balanites aegyptiaca* was conducted using the fruits of the plant from local crude drug market, the whole fruit was used for the study of macroscopic and microscopic characters. Saponins isolated from *B. aegyptiaca* exhibit a powerful anti-cancer effect against human tumour cell lines (HT-29) (Hassan et al., 2016; Murthy et. al., 2021). Macro and Microscopical and physicochemical pharmacopeial standards for the fruit of *B. aegyptiaca* have been derived as per standard methods. Phytochemical entities such as carbohydrate, trierpene, phytosterol, saponins, amino acids and coumarins were detected by colour tests (Al-thobaiti and Zeid, 2018; Chapagain, 2006). HPTLC fingerprint profile has also been recorded for identification of different extracts of *B*, *aegyptiaca* (Narayana *et. al.,* 2016).

The mesocarp of the fruit is widely used as an oral medicine for diabetics in Egyptian herbal medicine (Nasseret. al., 2016). The oil obtained from the fruit is used in dressing of wound and as an embrocation in rheumatism (Iwu, 2014; Wawata et al., 2018).

The stem's bark of *B. aegyptiaca* methanol extract has been found to exhibit potent antiangiogenic, antiproliferative and antitumor properties (Hassan et al., 2016; Nadro and Samson, 2014). The bark decoction is used as an abortifacient, the fruit is used for the treatment of liver and spleen diseases, and the fruit pulp is a mild purgative. Furthermore, the **roots** are used for abdominal pains and as a purgative. Gum from the wood is mixed with maize meal porridge to treat chest complaints (Aliero and Bunza, 2016). The roots and fruits of *Balanites* contain diosgenin, which used is in the production of oral contraceptive, sex hormone and anabolic steroids (Kant and Gour, 2015). They have insecticidal, anthelmintic, anti feedant, molluscidal and contraceptive properties (Kingston, et. al. 2011).

A combination of the bark and fruit are deadly to small freshwater snails' intermediary host to bilharzia and hence used for the control of schistosomiasis (Murthy et. al., 2021).In Northern Nigeria, the roots and barks of Desert date tree are used as a purgative and are considered ichthyotoxic and anthelmintic. In times of famine the leaves, flowers, buds, fruits and even bark are relied on as a source of food. The root extracts are curative against malaria (Chothani and Vaghasiya, 2011).

Balanites aegyptiaca as a source of food

Many parts of the plant are used as food by different peoples according to culture. The different parts of the trees are generally cheap in the market regardless of its use in the arid and semi-arid regions of Africa (Kobbail et. al., 2020; Joel, 2018). For example, the leaves of the plant are cooked by local people in Uganda. These cooked leaves are marketed by women and children in *katakwi* (North eastern Uganda) (Chothani and Vaghasiya, 2011). *Balanites* kernels are also cooked and eaten in the form of food called '*Kwaikwaye'* by Hausa tribe in Northern Nigeria (Iwu, 2014; Wawata et al., 2018). The kernel is rich in oil (38.2-54.7%) and presents up to 75% unsaturated fatty acids among the total fatty acids (Fregon, 2015; Abuelhamd et al., 2016). It was reported that rural women in Nwamunshi and Jenpetel village in Taraba state of Northern Nigeria, used *Balanites aegyptiaca*'s seeds to extract cooking oil which is highly valued, 35cl of the oil is sold for 250-500 Naira (Nigeria's currency).The seed is used as a febrifuge. *Balanites* pulp can be made into alcoholic drink, when left for two days(Okia et al., 2013). The ripe fruits are licked during fruiting season. Therefore, ensure food security because of its high yield in drought prone areas (Kant, and Gour, 2015).

Balanites aegyptiaca a source of cosmetics

The seed kernel of *Balanites* is an excellent and important product that is rich in oil, protein, minerals which is reported to be used for over thousands of years including its use in cosmetics industry for making soap and lotion **(**Zang et al., 2018**)**.

Balanites aegyptiaca tree as a source of fuelwood (firewood) and charcoal

Fuelwood and charcoal are obtained from *Balanites tree species* (Ali et al., 2022). It produces a charcoal of high quality that is smoke-free as the wood is oily (Naibbi, 2015: Kobbail et al., 2020).

Balanites aegyptiaca tree as a source of kitchen and cooking utensils, farm implement and traditional school learning board

Larinde, and Aiyeloja, (2015), reported the use of the wood for kitchen utensils (such as chopping board, stool, pestle and mortar), handle of farm tools(rake, hoe, digger etc.), fencing pole, and slates for writing in traditional Islamic (Qur'anic) schools

Balanites aegyptiaca tree as a source of fodder

The seeds and leaves always popular with animals in drier areas especially where open grazing is practiced(The National Academies, 2008; Okia et al., 2013).

Balanites aegyptiaca tree as potential source of Biodiesel

Balanitesaegyptiaca have proven to be a potential tree species (Naik and Balakrishna, 2017). This was discovered in an attempt to reduce air pollution as a result of emission from automobile use of petrol and related products.
Balanites aegyptiaca's oil is also considered to be a good source for high cost and quality cosmetics used by ancient Egyptian royalty. A chemical characterization of the plant was conducted and the result showed that the plant is an excellent resource for biodiesel making**(**Dominique et al., 2018; Pam et al*.,* 2018; Chomini and Daspan et al**.,** 2020; Jamil and Mohammed, 2020; Usman and Rufai, 2020).

The fuel properties were determined in accordance with the Association of Official Analytical Chemists (AOAC, 1990), an American society for Testing and Material (ASTM D 6751) and European standard methods. The findings of Usman and Rufai, (2020) suggest *Balanites aegyptiaca* as a raw material for biodiesel production which is suitable alternative fuel for communities in dryland areas of Nigeria **(**Usman and Rufai, 2020**).** There were many previous studies that showed the potentiality of *Balanites aegyptiaca* as a source of biodiesel **(**Mercyakaagerger and Giwa, 2016;Dominique et al., 2018; Pam et al*.,* 2018; Chomini and Daspan et al**.,** 2020; Jamil and Mohammed, 2020)**.**

Roles of Balanites aegyptiaca in addressing environmental problems

Balanites offers ways to help address pressing environmental problems such as desertification, and prevention of soil erosion (Gumbo, 2010).

Other roles of Balanites aegyptiaca tree species

Balanites aegyptiaca offers ways to provide shade for animals, and habitat for birds and insects (Gumbo, 2010). A study byHanadiet al. (2020) revealed the excellent properties of the *Balanites* wood essential for the production ofpaper and flooring materials.

Conclusion

*Balanites aegyptiaca*is well adapted to a wide range of habitats, soil types and climates. It is one of the most important tree species for African and Asia as it provides food, medicinal products, fuelwood and charcoal, source of Biodiesel, source of kitchen and cooking utensils, farm implement and traditional school learning board, and a tree used to address environmental problems such as desertification control and prevention of soil erosion. This calls for a massive production and planting of the tree species, as well as stimulating its natural regeneration. Some of the noticeable constrains for the silvics of the tree includes slow growth phase, less tolerant to grazing of livestock, and lack of adequate knowledge of various strategies for In situ and Ex-situ conservation, scientific methods of its production for intensive planting, which this review highlighted. This article will benefit researcher, teachers, forest genetist, silviculturist, horticultural societies, and other relevant organizations that focus on plants, trees and environmental protection.

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APPENDIX 1: Summary of reviewed literature on the manuscript titled: Exploring the Silviculture and Silvics of Desert date (*Balanites aegyptiaca*) in Northern Nigeria: Opportunities for Economic, Social and Environmental Development.

Authors and Date	Title	Country	Dimension of Article	Type of research	Published in
Abdallah A.M.A., Hanadi M.S., and G.H.H. (2020).	*Balanites aegyptiaca*: A Multipurpose Tree Species for Forest Based Industry Development in Sudan.	Sudan	*Balanites aegyptiaca*	Review	Journal
Abuelhamd El. Saye M.; Wael H.M., Armindo M.; Susana C., and Isabel, M. P. (2016).	Enzymatic Extraction of Oil From *Balanites Aegyptiaca* Kernel and Comparison With Solvent Extracted Oil.	General	*Balanites aegyptiaca*	Experimental	Journal
Adebayo, O., Olagunju, K., Kabir, S.K., and Adeyemi, O. (2016).	Social Crisis, Terrorism and Food Poverty Dynamics : Evidence from Northern Nigeria.	Nigeria	Poverty and Livelihood	Review	Journal
Adeniran, M.A., and Daramola, M.A. (2018).	Trends in Preventing Medicinal Plants from Extinction in Ado Local Government Area of Ekiti State, Nigeria.	Nigeria	Medicinal plant	Mixed Method research	Journal
Aduradola, A.M. (2012).	*The Forest of Hope : Pains and Gains in Tropical Silviculture*	General	Silviculture	Review	Journal
Akinyetun, T.S., Alausa, J.A., Odeyemi, D.D., and Abuton, .A.S. (2021).	Assessment of the Prevalence of Multidimensional Poverty in Nigeria : Evidence From Oto /Ijanikin, Lagos State.	Nigeria	Poverty and Livelihood	Qualitative	Journal
Ali, B., Saadun, N., Kamarudin, N., Azani, A.M., and Nawi, M.N. (2022)	Structure and Characteristics of Fuelwood Supply Chain in Yobe, Nigeria.	Nigeria	Fuelwood	Qualitative	Journal
Al-thobaiti, S.A., and Zeid, I.M.A. (2018).	Phytochemistry and Pharmaceutical Evaluation of *Balanites aegyptiaca*: An overview.	General	*Balanites aegyptiaca*	Experimental	Journal
Aliero, M.M., and Bunza, M.R. (2016).	The growth of Balanites aegyptiaca (L .) seedlings under varied watering intervals in the nursery	General	*Balanites aegyptiaca*	Experimental	Journal
AOAC (1990). *AOAC International. 9 CFR 318.19(b). AOAC: Official Methods of Analysis (Volume 1).*	Association of Official Analytical Chemists *CFR Section(s):*	*Washington, D.C.*	*Standards Body for methods of analysis*	Review	*Report*
Ashton, M. S. (2000).	*The Silvicultural basis for Agroforestry systems*.	General	Silviculture	Review	Journal
Bishnu P. et. al., (2006).	Bio production of Diosgenin in Callus Cultures of Balanites aegyptiaca : Effect of Growth Regulators. Natural Product Communications, 1(3), 215–221.	General	Balanites aegyptiaca	Experimental	Journal
Chapagain, B.P. (2006).	Characterization Of Desert Date (Balanites aegyptiaca) Saponins and their biological activities.	General	Balanites aegyptiaca	Experimental	Journal
Cecilia A., et. al., (2019).	Wild Plants for a Sustainable Future: 110 multipurpose species	General	Wild plants	Review	Journal
Chomini, M.S., Daspan, A.J., Kambai, C. (2020).	Assessment of Biodiesel Fuel Potentials of Seed Crude Oil Extracts of *Balanites aegyptiaca*(L.).	General	*Balanites aegyptiaca*	Experimental	Journal
Chothani, L.D., and Vaghasiya H.U. (2011)	A review on Balanites aegyptiaca Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. Pharmacognosy Reviews.	General	*Balanites aegyptiaca*	Review	Journal
Larinde, S.L., and Aiyeloja, A. (2015),	Contribution of Mortar and Pestle Production to Rural Livelihood in Southwest Nigeria.	Nigeria	*Poverty alleviation and* Livelihood i	Qualitative	Journal
Dominique, L., et. al., (2018).	Biofuel from *Balanites aegyptiaca :* Optimization of the Feedstock Supply Chain.	General	*Balanites aegyptiaca*	Experimental	Journal
Eldin, K., and Fadl, M. (2014).	Balanites aegyptiaca (L.): A multipurpose fruit tree in savanna zone of Western Sudan	Sudan	*Balanites aegyptiaca*	Review	Journal
Elfeel, A.A. (2012).	Effect of seed pre-Treatment and sowing orientation on Germination of Balanites aegyptiaca (L) DEl. seeds.	General	*Balanites aegyptiaca*	Experimental	Journal
Elmugheira M.I. (2021).	Anthropogenic pressure on Tree species Diversity , Composition , and Growth of Balanites aegyptiaca in Dinder Biosphere reserve, Sudan.	Sudan	*Balanites aegyptiaca*	Mixed research method	Journal
Fregon, S.M.E. (2015).	Physicochemical Properties of Balanites aegyptiaca (Laloub) Seed Oil.	Sudan	*Balanites aegyptiaca*	Experimental	Journal

Furo, R.M.J. (2014).	Dynamics of poverty, deforestation and beekeeping in Northern Nigeria concerns for policymakers.	Nigeria	Poverty and Livelihood	Review	*Scientific Papers Series (report)*
Gaisamudre, K.N., and Sarwade, P.P. (2021).	Effect of Different Treatments on Seed Germination of Balanites aegyptiaca	General	*Balanites aegyptiaca*	Experimental	Journal
Gumbo, E.N.C. (2010).	*The Dry Forests and Woodlands of Africa Managing for Products and Services*	Africa	Forest management	Review	*Report*
Gunter, A., Weber, M., Stimm, B., and Mosandi, R. (2011).	Silviculture in the Tropic in Tropical Forestry	General	Silviculture	Review	E book
Hassan, L.E.A. et. al., (2016).	Chemotherapeutic potentials of the stem bark of *Balanites aegyptiaca* : an antiangiogenic, antitumor and antioxidant agent. *BMC*	General	*Balanites aegyptiaca*	Experimental	Journal
Henry, G.A., Brooks, S.A., and Piperno, R.D. (2014).	Plant foods and the dietary ecology of Neanderthals and early modern humans.	General	Food and Evolution	Review	Journal
Ibrahim, E.S. et. al., (2022).	Desertification in the Sahel Region : A Product of Climate Change or Human Activities ? A Case of Desert Encroachment Monitoring in North-Eastern Nigeria Using Remote Sensing Techniques.	Nigeria	Desertification	Mixed methods	Journal
Iqbal, A.M. (2017).	Enhancing propagation and growth of *Balanites aegyptiaca* through seed treatment.	General	*Balanites aegyptiaca*	Experimental	Journal
Iwu, M. (2014).	Hand book of African medicinal Plants	Africa	Medicinal plants	Review	Book
Jaiyeola, A.O., and Choga, I. (2020).	Assessment of poverty incidence in Northern Nigeria Journal of Poverty, 1–18.	Nigeria	Poverty alleviation and livelihood	Qualitative (Survey)	Journal
Jamil, F, andMohammed, L.A.H. (2020).	Waste Balanites aegyptiaca seed oil as a potential source for biodiesel production in the presence of a novel mixed metallic oxide catalyst.	General	*Balanites aegyptiaca*	Experimental	Journal
Joel, E. (2018).	Productivity and conservation practices for Balanites aegyptiaca (Desert date).	Uganda	*Balanites aegyptiaca*	Review	Thesis
Joker, L.S. (2000).	Balanites aegyptiaca (L.) Del. Seed Danida Forest Seed Centre	Denmark	*Balanites aegyptiaca*	Review	leaflet
Kamal, Met. Al., (2019).	Vegetative Propagation of Balanites aegyptiaca by Air Layering under Sahelian Climate in Niger.	Niger republic	*Balanites aegyptiaca*	Experimental	Journal
Kant, T, and. Gour, V.S. (2015).	Balanites aegyptiaca, (L). A Multipurpose and potential Biodiesel Tree Species of the Arid Region. ;7(2) http://www.sciencepub.net/report	Arid Zone	*Balanites aegyptiaca*	Review	Report
Nasser S. Abou Khalil, Alaa S. Abou-Elhamd, Salwa I. A. Wasfy, Ibtisam, M. H. ElMileegy, Mohamed Y. Hamed, and Hussein M. Ageely(2016).	Antidiabetic and Antioxidant Impacts of Desert Date (*Balanites aegyptiaca*) and Parsley (Petroselinum sativum) Aqueous Extracts : Lessons from Experimental Rats.	General	*Desert Date (Balanites aegyptiaca) and Parsley (Petroselinum sativum)*	Experimental	Journal

Kobbail, A.A., and Abaker, A.M., Salih, M.E., Abdallah, S.M (2020).	Local People's knowledge on Uses, Threats and Conservation Measures of *Balanites aegyptiaca* (L.) Del. Heglig Tree in Sudan	Sudan	*Balanites aegyptiaca*	Qualitative (Survey)	Journal
Larinde, S.L., and Aiyeloja, A. (2015)	Contribution of Mortar and Pestle Production to Rural Livelihood	Nigeria	*Trees of the Arid zone / Sahel*	Qualitative Research	Journal
Mansor, N. et. al., (2003).	In vitro multiplication of the semi-arid forest tree, *Balanites aegyptiaca* (L) Del.	General	*Balanites aegyptiaca*	Experimental	Journal
Massaoudou, M., Tougiani, A., and Damme, P.V. (2022).	Development of Vegetative Propagation Strategies for *Balanites aegyptiaca* in the Sahel, Niger.	Niger Republic	*Balanites aegyptiaca*	Experimental	Journal
Mbah, J.M., and Retallick, S.J. (1992).	Vegetative propagation of Balanites aegyptiaca (L.) Del.	General	*Balanites aegyptiaca*	Review	Journal
Mercyakaagerger, S., and Giwa, S.O. (2016).	Production of Biodiesel from Desert Date Seed Oil.	General	*Balanites aegyptiaca*	Experimental	Journal
Mohamed, A., and Bekhit, M.H. (2007).	In vitro propagation of *Balanites aegyptiaca* (L) DEL An Endangered Medicinal Plant .	General	*Balanites aegyptiaca*	Experimental	Journal
Mohammed, A. et al., (2010).	In vitro clonal propagation of *Balanites aegyptiaca*	General	*Balanites aegyptiaca*	Experimental	Journal
Moussa, M., Abasse, T.,Rabiou, H., Aboubacar, M.,, and Mahamane, L. (2020)	Analysis of the Fruit Value Chain of Two Priority Food Woody Species	NigerRepublic	*Balanites aegyptiaca*	Experimental	Journal
Mukhtar, R.B. (2018).	Effect of rooting media and hormone concentrations on vegetative propagation of Balanites aegyptiaca.	General	*Balanites aegyptiaca*	Experimental	Journal
Murthy, H.N., et al., (2021).	Phytochemicals and Biological Activity of Desert Date (Balanites aegyptiaca (L.) Delile). *Plants*,	General	*Balanites aegyptiaca*	Experimental	Journal
Nadro, M.S., and Samson, F.P. (2014)..	The effects of *Balanite aegyptiaca* kernel cake as supplement on alloxan -induced diabetes mellitus in rats	General	*Balanites aegyptiaca*	Experimental	Journal
Naibbi, A.I. (2015).,	Traditional Energy Discourse : Situation Analysis of Urban Fuelwood Sourcing in Northern Nigeria.	Nigeria	Fuelwood	Review	Journal
Naik, N.S., and Balakrishna, B. (2017)	Assessment of toxic content in *Balanites aegyptiaca* seed cake and use of enzymatic- catalysed biodiesel in diesel engine enzymatic- catalysed	General	*Balanites aegyptiaca*	Experimental	Journal
Nanang, D. M. (1996).	*The Silviculture, Growth and yield of neeem (Azadirachta indica A. juss.*	General	*Balanites aegyptiaca*	Mixed method	Journal
Narayana, K., et.al., (2016).	Pharmacognosy and quality characterization of *Balanites aegyptiaca* (L .) Delile fruits.	General	*Balanites aegyptiaca*	Experimental	Journal

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