



Jojoba (*Simmondsia chinensis* (Link) Schneider): An important Medicinal Plant- The Gold of the Desert

Raju K. Chalannavar ¹, Hosamani PA ² and Ravindra B. Malabadi ^{1,3,*}

¹ Department of Applied Botany, Mangalore University, Mangalagangothri-574199, Mangalore (DK), Karnataka State, India

² Department of Botany, Bangurnagar Arts, Science and Commerce College, Dandeli-581325, Karnataka State, India

³ Miller Blvd, NW, Edmonton, Alberta, Canada.

GSC Advanced Research and Reviews, 2026, 27(02), 160-170

Publication history: Received on 12 April 2026; revised on 20 May 2026; accepted on 28 May 2026

Article DOI: <https://doi.org/10.30574/gscarr.2026.27.2.0122>

Abstract

Jojoba [*Simmondsia chinensis* (Link) Schneider] is an evergreen, perennial and drought resistant shrub belongs to the family of *Simmondsiaceae*. It is a potential seed oil crop for desert region, known as the gold of desert. Its seeds and oil have a long history of use in folklore to treat various ailments, such as skin and scalp disorders, superficial wounds, sore throat, obesity, cancer, improvement of liver functions, enhancement of immunity, and promotion of hair growth. This plant has unique oil among plant kingdom which is chemically a liquid-wax. The main uses of liquid-wax in various industries like cosmetics, pharmaceuticals, petrochemicals and lubricants. The seed cake is used safely as a food and has many applications in the food industry due to its high fat and protein content. Extensive studies on Jojoba oil showed a wide range of pharmacological applications, including antioxidant, anti-acne and anti-psoriasis, anti-inflammatory, antifungal, antipyretic, analgesic, antimicrobial, and anti-hyperglycemia activities. Jojoba is a cross pollinated plant and crop having tendency to produce seedlings of varying size and yield. Therefore, this heterozygous progeny has raised doubt about economic feasibility of jojoba crop at commercial scale. The commercial plantations of jojoba raised successfully in Bikaner district of Rajasthan, India.

Keywords: Gold of Desert; Jojoba; India; Liquid-wax; Oil crop; Rajasthan; *Simmondsia chinensis*

1. Introduction

Jojoba [*Simmondsia chinensis* (Link) Schneider] is evergreen, perennial and drought resistant shrub belongs to the family of *Simmondsiaceae*. It is a potential seed oil crop for desert region, known as the gold of desert [1-20-56-96]. The other names of jojoba are hohoba, coffee berry, goat nut, deer nut, pig nut, coffee bush and lemon leaf. Jojoba (*Simmondsia chinensis*) (Link) Schneider is native to North and Central American deserts but cultivated worldwide in India, Israel, Australia, USA, Mexico, Chile, Egypt, and Argentina [1-20-56-96]. Jojoba [*Simmondsia chinensis* (Link) Schneider] is a potential seed oil plant that have played role in combating edge effects of desertification in the Thar Desert in India [3-20, 26, 37, 46, 75,79,88,94-96]. The arid lands of Rajasthan are all set to make a revolution in Indian agriculture, with planned large scale cultivation of the exotic Jojoba plant. Arid western plain and semidried Eastern plain of Rajasthan, Western agro climatic zone of Haryana, Western plain agro climatic zone of Punjab, Southern western semi arid zone of Uttar Pradesh, Saurashtra and Kutch region of Gujarat, Coastal region of Orissa, Coastal Telangana region and Andhra Pradesh were also considered by the Govt of India for the large scale farming of Jojoba [3-20, 26, 37, 46, 75,79,88,94-96-100]. However, jojoba (*Simmondsia chinensis*) is a commercially important woody oil crop whose productivity is limited by low-temperature sensitivity[98-100].

* Corresponding author: Ravindra B. Malabadi.

Jojoba [*Simmondsia chinensis* (Link) Schneider] is a small tree like shrub which is a long living dioecious, evergreen shrub. Thick leathery bluish green leaves and usually bushy, it is a long lived, dioecious, drought resistant plant often reaching heights of three meters or more under ideal growing conditions[1-20-56-96]. Seed from the Jojoba plant is the only botanical source of commercial quantities of unsaturated straight chain wax esters. Seed contains 45 to 55% oil or liquid wax, with chemical properties similar to those of the body fat obtained from sperm whale [1-20-56-96-98-100]. It has no traces of resins, tars or alkaloids and contains a very small amount of saturated wax, tocopherols, steroids and hydrocarbons. An oblong to oval seed produced by the female Jojoba plant weighing 0.2 - 1.5 grams each with a diameter of 3-15 mm and which at maturity is reddish brown with a wrinkled surface [1-20-56-96]. Jojoba (*Simmondsia chinensis*) has rapidly grown into a vital botanical asset, driven by a global market projected to surpass \$270 million[1-20-56-96-98-100]. Valued for its lightweight, non-comedogenic liquid wax esters, it remains a staple for balancing sebum in skin and hair care. Recent agricultural research focuses on stress resilience, propagation, and eco-friendly uses[1-20-56-96-98-100].

2. Jojoba [*Simmondsia chinensis* (Link) Schneider]: Medicinal value

Jojoba is a widely used medicinal plant that is cultivated worldwide. Its seeds and oil have a long history of use in folklore to treat various ailments, such as skin and scalp disorders, superficial wounds, sore throat, obesity, and cancer; for improvement of liver functions, enhancement of immunity, and promotion of hair growth [1-26-59-67-88-96-100]. It is a multipurpose oil seed crop mainly grown in desert regions of world. This plant has unique oil among plant kingdom which is chemically a liquid-wax[1-26-59-67-88-96-100]. The liquid-wax is made up of an ester of long chain fatty acids and alcohols. The liquid-wax is unique in nature because have no traces of glycerine and easily modified via hydrolysis, hydrogenation, halogenation, sulfurization, phosphosulfurization and ozonization techniques[1-20-56-96-100]. The main uses of liquid-wax in various industries like cosmetics, pharmaceuticals, petrochemicals and lubricants[1-26-59-67-88-96]. Extensive studies on Jojoba oil showed a wide range of pharmacological applications, including antioxidant, anti-acne and antipsoriasis, anti-inflammatory, antifungal, antipyretic, analgesic, antimicrobial, and anti-hyperglycemia activities[1-26-59-67-88-96-100]. In addition, Jojoba oil is widely used in the pharmaceutical industry, especially in cosmetics for topical, transdermal, and parenteral preparations[1-26-59-67-88-96]. Jojoba oil also holds value in the industry as an anti-rodent, insecticides, lubricant, surfactant, and a source for the production of bioenergy [1-29-79-87-88-96]. Jojoba oil is considered among the top-ranked oils due to its wax, which constitutes about 98% (mainly wax esters, few free fatty acids, alcohols, and hydrocarbons). In addition, sterols and vitamins with few triglyceride esters, flavonoids, phenolic and cyanogenic compounds are also present[1-26-59-67-88-96-100].

Jojoba (*Simmondsia chinensis*) is an emerging woody crop valued for its oil production and is native to the Sonoran Desert region in North America [1-98-100]. It is classified under the order *Caryophyllales* and represents the sole taxon within the *Simmondsiaceae* family[98]. Its seeds contained abundant liquid wax esters, with total oil reaching ~65%, of which approximately 97% were monoesters formed by long-chain fatty acids and fatty alcohols, while triacylglycerols occurred only in trace amounts. These wax esters exhibited excellent thermal resistance, chemical stability, and lubricity, making jojoba oil an ideal substitute for spermaceti [1-98]. As such, it was widely utilized in the pharmaceutical, cosmetics, and aerospace industries. Market analyses indicated that the global jojoba oil industry represented a several-hundred-million-dollar market with sustained growth potential. In recent decades, the notable economic value of jojoba has prompted its introduction and cultivation in various countries. However, its limited tolerance to low temperatures significantly restricted its distribution in dry regions with moderate climates[1-98-100]. Moreover, jojoba frequently experienced abiotic challenges such as drought, UV exposure, and salinity, which adversely affected its growth and oil traits[98-100]. Zhu et al., (2026) [98] are of the opinion that given the high economic value of jojoba oil and the strong limitations imposed by abiotic stresses on its cultivation, elucidating stress-response mechanisms and identifying key genes for abiotic stress tolerance are critical for genetic improvement and the development of stress-resilient cultivars[98].

3. Jojoba [*Simmondsia chinensis* (Link) Schneider]: Farming in India

Jojoba, *Simmondsia chinensis* link Schneider has attracted wide spread attention over the last 30 years. The plant is native to Sonoran Deserts of Northwestern Mexico and Baja California. Various agencies/organizations have assessed its future demand in the world market owing to its remarkable similarity to sperm whale oil in chemical composition and as a substitute for sperm oil[1-94-95]. The USA, Mexico, Australia, Israel and India have started producing jojoba oil on commercial basis [1-3-20, 26, 37, 46, 75,79,88,94-96]. Central Arid Zone Research Institute, Jodhpur, India (CAZRI), started research work on this plant as early as 1965. Further, Central Salt and Marine Chemical Research Institute, Bhavnagar, India (CSMCRI) undertook a test plantation during 1979 for evaluation of its economic value under brackish water/saline conditions[3-20, 26, 37, 46, 75,79,88,94-96]. The cultivation of jojoba on commercial scale has

started recently. Realizing its adaptability and economic importance, the Association of Rajasthan Jojoba Plantation and Research Project, India (AJORP) has established large-scale plantations of jojoba in different locations of Rajasthan and now jojoba seeds are commercially available from Indian locations[3-20, 26, 37, 46, 75,79,88,94-96]. Earlier work carried out at the Indian Institute of Petroleum, Dehradun includes studies on jojoba oil procured from M/s Janco. Jojoba Oil and Seeds Co., Arizona, USA as a lubricant, additive and a source of specialty chemicals as well as modifying oil for industrial applications like extreme pressure additives and jojoba wax[3-20, 26, 37, 46, 75,79,88,94-96].

The need was felt to study the quality of seeds/oils from various Indian locations and the effect of storage time on the quality of oil to establish the shelf life of the oil. There are huge tracts of arid and semi arid lands in India where it has the potential to grow as an important commercial crop[3-20, 26, 37, 46, 75,79,88,94-96]. Jojoba oil is unique in nature among plant kingdom. The jojoba oil has gain a lot of importance in various industries. In 1995, an association of Rajasthan Jojoba Plantation and Research Project (AJORP) was set up by Government of India with 100% funding from the Department of Land Resource, under Ministry of Rural Development[3-20, 26, 37, 46, 75,79,88,94-96].

The Centre for Jatropha Promotion and Biodiesel (CJP) is a global jojoba world which focuses on commercialization of entire jojoba in arid and semi-arid regions of India[3-20, 26, 37, 46, 75,79,88,94-96]. There is high consumption of natural resources due to the increasing population. The resultant demand for green energy amidst fossil fuel shortages has rekindled interest in Jojoba oil (*Simmondsia chinensis* (Link) Schneider). Jojoba oil is the only unsaturated liquid wax readily extractable in large quantities from plant sources ($\approx 52\%$ of the total seed weight), which shows a high structure similarity with the sperm whale oil [3-20, 26, 37, 46, 75,79,88,94-96]. This similarity has increased the interest in Jojoba oil as a replacement for sperm whale oil (spermaceti wax) since the 1970s [1-96].

Jojoba oil is a source of specialty chemicals and its uses for industrial application are gaining in adaptability and importance. For prolong use of jojoba oil, the details of its storage behavior are required [3-20, 26, 37, 46, 75,79,88,94-96-100]. In one of the study by Kaul et al., (2009) [94] reported that the ageing effect on the quality of oils was studied for oils from five locations of Rajasthan (India) [94]. The oils were extracted/expelled from the seeds that contained 2.5–3.9 wt.% moisture and 42–50 wt.% oil [94]. Physico-chemical properties were determined by standard analytical test methods. Effect of storage time on quality of solvent extracted oil samples with respect to acid value, iodine value, saponification value and peroxide value were determined[94]. The samples were stored for 18 months in the laboratory under climatic condition prevailing in Dehradun (India) during study period [94]. The analysis of samples was done at an interval of 3 months. The properties of jojoba oils compare well with the International Jojoba Expert Council (IJEC) specifications[94]. During storage, acid values, iodine values and peroxide values of the oil increase with time while saponification values remain almost unchanged [94].

4. Jojoba (*Simmondsia chinensis*): Commercial Value

Jojoba (*Simmondsia chinensis*) attracted a great deal of scientific, commercial and popular interest when the unique properties of its seed oil first became known in the 1970s [1-96]. A shrub native to the Sonoran and Mojave deserts of Mexico, Arizona and California, it is promising crop for hot dry areas throughout the world [1-23-35-45-58-69-78-88-96-100]. Half the weight of the plant's large seeds is made up of liquid wax. The oil is colorless, odorless, and does not turn rancid like other plant oils[1-96]. The molecules are long straight chains of 36-46 carbons with few side-chains attached, so the oil penetrates the skin readily, which is why it is so prized in cosmetics. The oil also has applications in industry as a lubricant and as a potential source of biodiesel fuel. Currently, the main market for jojoba oil is the cosmetics industry[1-96]. The oil is used in a wide variety of hair and skin care products. But the market could be much bigger if a way could be found to mechanically harvest the seeds [1-56-77-87-96-100]. Presently, seeds must be harvested by hand, and yields are variable, ranging from 340 to 900 kg per hectare[1-96]. It takes 4-5 years to get a first crop, but the long life of the crop means that the crop can generate revenue for many years from a single planting.

According to the Association of Rajasthan Jojoba Plantation and Research Project (AJORP), the cost of production of jojoba seeds in India is much lower than in other parts of the world, about USD \$0.70/kg in India compared to \$1.50/kg in Israel and \$3/kg in the United States[1-96]. World demand for jojoba oil was about 40,000 tones in 2002, so the prospects seem bright for Indian producers many of whom, are just starting to get seed harvests[3-20, 26, 37, 46, 75,79,88,94-96]. The high cost of extracting the oil from the seeds is another factor that may limit market potential, particularly its use in biofuels. At current costs, the price of jojoba oil ranges between USD \$13-32 per kilogram. Much research work is needed to reduce costs if jojoba is ever going to be a serious candidate for biodiesel fuel [1-3-20, 26, 37, 46, 75,79,88,94-96].

Jojoba was widely used by Native Americans in the Sonora desert (California) as a foodstuff in the form of cooked fruits and in oil form as a therapeutic for multiple ailments: cancer therapy, liver and kidney disorders, obesity, parturition, sore throat, superficial wound healing, warts, psoriasis, acne, sunburn, and treatment of poison ivy exposure [1-56-77-87-96]. Jojoba oil is widely used in the pharmaceutical industry, especially in cosmetics, to restore the ordinary health of hair and skin. The leaf extract, combined with extracts from other plants, also acts as anti-inflammatory agents to treat sensitive skin stress [1-56-77-87-96]. Jojoba cosmetic products currently on the market include the following: bath oil, body oil, cleansing creams, cleansing pads, cleansing scrubs, nourishing facial cream, facial oil, hair conditioner, hair oil, makeup remover, and shaving cream [1-56-77-87-96].

In addition, the oil has many industrial applications that include an extreme temperature/extreme pressure lubricant in the form of sulfurized oil, which can bear high temperature and pressure without changing its viscosity [1-56-77-87-96]. Other industrial uses include the extraction and separation of isotopes such as Uranium (VI), Thorium (IV), and Plutonium (IV); in the leather industry as a fat liquor with good tanning properties; as a surfactant, fire retardant, lamp oil, candle wax, polishes, and antifoaming agents in isolation of penicillin and tetracycline [1-56-77-87-96].

The global jojoba oil market is estimated to reach \$272.4 million by 2026, according to a new report by Reports and Data [97]. This can be mainly associated with the growth in cosmetic manufacturing, development of alternative bio-lubricant feedstock demand – particularly in developed markets of Europe and North America – and the high nutritional value of jojoba oil [97]. Rising concern regarding the side effects of synthetic and chemical additives used in cosmetics and food and beverages is boosting demand for natural alternatives, like jojoba oil, in the market [97]. However, long-term jojoba oil production diversifies on the regular supply of resources and capabilities to replace industrial oil with several applications at a relative price. The production yield of the crop profoundly varies on the farming process [97]. Jojoba oil is a form of vegetable oil that can be obtained from *Simmondsia chinensis*, which is the crushed beans of the jojoba shrub [97]. By composition, it is close to sebum and is a form of polyunsaturated liquid wax [97]. Due to this reason, it can be easily absorbed by the skin, without any allergic reactions, and diminishing the growth of any fungal and bacterial microbes that can attack the skin [97]. It regulates and re-balances oil production in oily skin and also provides nourishment to dry skin. Various skin care brands have replaced animal fats and adopted the use of jojoba oil for manufacturing creams and skin lotions [97].

5. Jojoba (*Simmondsia chinensis*): Desertification

Bal (2021) [95] reviewed that desertification is recognized as a major threat to global biodiversity and a burning issue to environment today [95]. Jojoba (*Simmondsia chinensis*) is a commercially important woody oil crop whose productivity is limited by low-temperature sensitivity. The desert land starts to degrade its chemical, physical and biological productivity [1-56-77-87-96]. The lands get affected with a combination of various factors like deforestation, overgrazing, unsustainable agricultural practices, over exploitation of soil, poverty and climate change. Deforestation is one of them root cause of desertification [1-95]. India has developed Biodiversity Action Plans to counter its causes and their effect, management and conservation of endangered flora and fauna [1-3-20, 26, 37, 46, 75,79,88,94-96]. Various environmental organizations focus on restoration of such land to control the desertification mainly in dry land areas [1-3-20, 26, 37, 46, 75,79,88,94-96]. The NGOs focus primarily on educating the local peoples about the danger of deforestation and employ them to grow the valuable economically important plants which are easily grows in desert land. Jojoba has very promising scope for cultivation in desert ecosystem even in the relatively hot weather [1-3-20, 26, 37, 46, 75,79,88,94-96]. Its nature withstand in warm weather in summer and cold weather in winter at low fertility of soil. The plant need has less amount of water compared to other economic crop like olive plant with great ability to withstand in high salt in soil [1-2-95]. The commercial plantation of jojoba is encouraging mainly in Thar Desert in India [1-3-20, 26, 37, 46, 75,79,88,94-96]. It is also known as gold of desert because it has valuable industrial application and easily grows on desert land [1-3-20, 26, 37, 46, 75,79,88,94-96].

Jojoba plantations played a vital role in combating edge effects of desertification and improve soil quality and restores land quality [4, 95]. It is a potential oil-seed crop. and helps in soil conservation, landscaping, open natural range lands and national parks [1-3-20, 26, 37, 46, 75,79,88,94-96]. Seed hulls can be used as a mulch or protective ground cover to reduce evaporation, erosion and weed growth and can be used as fertilizers and soil replenishes for the soil which is low in organic matter. Jojoba is a valuable seed oil crop useful in preventing wind erosion in desert regions. It is already being used as an ornamental shrub throughout the southern United States [1-5- 96].

Bal (2021) [95] reported that Jojoba has the distinction of being the commercial crop successfully in desert of Rajasthan, India [1-3-20, 26, 37, 46, 75,79,88,94-96]. To meet the demand of future its needs to be cultivated in huge amounts which are easy in desert land as well as wasteland reclamation [1-3-20, 26, 37, 46, 75,79,88,94-96]. Soil texture is an important parameter for best growth in sandy and decomposed rocky soil. Even if the fertility of soil is marginal, jojoba

is still able to produce well without use of fertilizers [1-3-20, 26, 37, 46, 75,79,88,94-96]. The irrigation system well established for jojoba plantation whether propagation by planting seedlings or stem cuttings. The drip watering system at root level to avoid evaporation of water so that plants use water maximally for better growth. Under ideal conditions of soil, water and sun, the tap root will grow an inch a day, within two years of planting [95]. The root system should reach the level of aquifer thus enabling sufficient growth for seed production without supplemental watering [1-3-20, 26, 37, 46, 75,79,88,94-96].

6. Jojoba (*Simmondsia chinensis*): Cross Pollinated Plant

Jojoba is a cross pollinated plant and crop having tendency to produce seedlings of varying size and yield [1-3-20, 26, 37, 46, 75,79,88,94-96]. Therefore, this heterozygous progeny has raised doubt about economic feasibility of jojoba crop at commercial scale. The need of jojoba growers for the successful commercialization depends upon selection of high yields germplasm and their further multiplication [1-29-96]. Propagation of jojoba crop is through direct seeding, seedlings, rooted cutting and plantlets produced from tissue culture techniques [1-3-20, 26, 37, 46, 75,79,88,94-96]. Commercial crop rose through direct seeds and seedlings are slow growing and requires three to four years to reach the flowering stage. These methods have limitation of male biased population which affects yields of crop [1-29-96]. When commercial plantation rose through direct seeding, about more than 50% seedlings are males. But the requirement of male population is only 10% seedlings [1-3-20, 26, 37, 46, 75,79,88,94-96]. The plant sex can be recognized only when plants start bearing flowers after 2–3 years of planting. Therefore, a major disadvantage of plantation raised through direct seeding method. To maximize the production, plantation raised through rooted cuttings from sex-specific plants (male or female) which are known to best quality of seeds with high level of oil content [1-3-20, 26, 37, 46, 75,79,88,94-96]. For commercial plantation with 90% female plants, leaving the 10% male plants to produce adequate pollen for all the female flowers [1-3-20, 26, 37, 46, 75,79,88,94-96]. However, only the female plants give the valuable seeds and requires more population in a commercial field [1-30-96]. Centre for Jatropha Promotion and Biodiesel (CJP) is a Global Jojoba World which focuses on commercialization of entire jojoba in arid and semi-arid regions of India [1-3-20, 26, 37, 46, 75,79,88,94-96]. In Bikaner district Rajasthan of India, the commercial plantation raised through the rooted cutting of high yielding germplasm [1-3-20, 26, 37, 46, 75,79,88,94-96]. The advantages of male and female cuttings used in a commercial field due to high uniformity of germplasm with high yield. The best planting time is spring season for well establishment of crop. Generally, jojoba crop produced an economically useful yield after four or fifth years of plantings [1-3-20, 26, 37, 46, 75,79,88,94-96].

Naturally, seed yield of jojoba range from a few seeds to as much as five kilogram seeds per plant. The seed yield varying from plant to plant and year to year production for a particular field. Average yield of seeds in a commercial plantation using selected higher yielding germplasm is capable of producing one to eleven tons per hectare after seventh to fifteenth years of planting [1-3-20, 26, 37, 46, 75,79,88,94-96]. The irrigation system in Thar Desert of Rajasthan through the drip irrigation system supply control by pressure regulators. Irrigation system must be in initial planting time mainly in spring and early winter seasons for maximum utilization of water for growth [1-31-96]. The commercial plantations of jojoba raised successfully in Bikaner district of Rajasthan, India and naturally flowering season of crops occurs in February to March. Bikaner, Rajasthan, India [1-3-20, 26, 37, 46, 75,79,88,94-96].

The commercial plantation of jojoba manages by the Centre for Jatropha Promotion and Biodiesel (CJP) through advanced crop practices adjustable to local soil quality, weather conditions, pest and disease control during frost time [1-3-20, 26, 37, 46, 75,79,88,94-96]. Therefore, the Centre for Jatropha Promotion and Biodiesel (CJP) developed a improved technology to ensure high yielding germplasm, crop management, irrigation system, fertilizers requirement, harvesting techniques, post-harvesting techniques and further grading-up process [1-31-96]. For the promotion of cultivation of jojoba as a commercial crop mainly on arid zones, the CJP organize the technical training programme on entire jojoba cultivation [1-3-20, 26, 37, 46, 75,79,88,94-96]. The training programmes includes the selection of land sites according to soil quality and weather conditions, seed bed preparations, seeding methods, germplasm selection, planting methods, irrigation process, manure and fertilizers addition, plantation male and female ratio obtaining high quality fruits, intercropping, weeds control, diseases and their control, predators and their control, harvesting techniques, drying and storage precautions [1-31-96]. The key factors governing profitability for large scale production of jojoba that the crop is grown under such conditions which are conducive to high commercial yield. Adverse rainfall and temperature conditions can limit the commercial production of the crop. Similarly, frost is a limiting factor to reduce the quality of production. Therefore, it is evident that jojoba plantations may survive in some marginal waste land [1-96]. In India, the CJP supervised the Jojoba Oil Farms to focus on the organic farming of jojoba from crop management to production of end product. Research on high yielding variety, best plantation methods with enhanced techniques has going on global scale [1-3-20, 26, 37, 46, 75,79,88,94-96]. However, the Centre for Jatropha Promotion and Biodiesel (CJP) keep watching on research towards jojoba breeding techniques and collecting the useful information related to jojoba cultivation methods [1-3-20, 26, 37, 46, 75,79,88,94-96]. The enhanced variety of jojoba with regards of seed and

oil yield with enhanced jojoba cultivation techniques may ensures early flowering and fruiting into profitable production of oil crop [1-3-20, 26, 37, 46, 75,79,88,94-96]. The success of commercial cultivation of jojoba depends upon high value of market which resides on improved yielding germplasm of both male and female plants. Agriculture industry hesitant to invest in a new technology to ensures the steady and continued supply of that resource [1-3-20, 26, 37, 46, 75,79,88,94-96]. Jojoba oil as an alternative oil in various industries and as a biofuel has been demonstrated. The jojoba crop has been proposed as gold of desert as it is highly profitable economical new oil seed crop being grown in India, Egypt, Australia and America[1-3-20, 26, 37, 46, 75,79,88,94-96]. In India, the development of jojoba cultivation including crop management, drip irrigation system and cost of production of one kilogram seeds is 0.5 \$[1-31-96].

Jojoba oil is edible and act as low calorie additive for vegetable oil. It contains a chemical compound simmondsin, which depress appetite. It does not rancid and may be suitable for vegetable oil [1-3-20, 26, 37, 46, 75,79,88,94-96]. The jojoba meal extract has high 30–35% protein content and major proteins are albumins (79%) and globulins (21%) [1-26-96]. It can also be used as a component of food additive, medical food or functional food. It has been found to be useful as supplement of diet for control of body weight in humans [1-27-96]. Jojoba meal has a potential use in animal feed but needs detoxification. It has a potential use as a fertilizer because of its high nitrogen content and can be used as soil amendment to enrich soil which is low in organic matter of desert land [1-28-96]. Jojoba is a potential seed oil crop of industrial importance mainly grows in the Thar Desert of Rajasthan, India[1-3-20, 26, 37, 46, 75,79,88,94-96]. The arid and semi-arid land of India are all set to make a revolution in Indian agriculture with planned large scale cultivation of the exotic jojoba plant. Jojoba in India is now being grown on area of about thousand hectares and the area is increasing every year[1-3-20, 26, 37, 46, 75,79,88,94-96]. About 90% of the jojoba cultivation is in Rajasthan in all over India. Jojoba bush is a valuable industrial plant for sustainable development of arid and semi-arid areas with rehabilitation of marginal land [1-3-20, 26, 37, 46, 75,79,88,94-96]. This plant can survive in different types of soil and resist to salinity and drought conditions. Therefore, this crop has a lot of economic importance with potential to restore the land's flora and fauna, improves soil quality and prevents the process of desertification. According to agronomist, the plantation of jojoba requires less water as compare to other oil seed crops in desert regions[1-3-20, 26, 37, 46, 75,79,88,94-96]. This crop does not require much attention as free from cattle attacks. The economic production is good as gives high income to the farmers as compares to other traditional crop. Further, the Centre for Jatropha Promotion and Biodiesel (CJP) can help to farmers to identifying the needs, opportunities and solution of local, regional and national markets values. For best farming system, the Centre for Jatropha Promotion and Biodiesel (CJP) directs to creating best business strategy for effective cultivation of jojoba[1-3-20, 26, 37, 46, 75,79,88,94-96].

7. Conclusion

Simmondsia chinensis (link) Schneider (commonly identified as jojoba but is also called deer nut, oat nut, wild hazel, and coffee berry) is a promising oil seed crop for the economic development of the arid and semiarid land all over the glob. The jojoba plant is a monogenetic dioecious grey-green shrub belonging to the family, *Simmondsiaceae*. Jojoba is considered a promising oil crop and is cultivated for diverse purposes in many countries. The jojoba seed produces unique high-quality oil with a wide range of applications such as medical and industrial-related products. The plant also has potential value in combatting desertification and land degradation in dry and semi-dry areas. Extensive biological and pharmacological investigations, based on the uses of jojoba oil in folk medicine, revealed that jojoba oil and its derivatives exhibit vast biological activities in different pharmaceutical forms, whether used topically or internally. These activities can be attributed to the unique chemical composition of the wax esters. Jojoba oil was reported for its use as a conditioning agent due to its emollient properties. The addition of jojoba oil to thioglycolate-based straightening emulsions benefited the hair fiber, allowing a little protein loss, protection to hair thread, and improved the breakage resistance. Jojoba oil has a wide range of industrial applications especially in polymers synthesis. Traditionally, it is used for many skin and scalp disorders. The seed cake is used safely as a food and has many applications in the food industry due to its high fat and protein content. Although the plant is known for its high-temperature and high-salinity tolerance growth ability, issues such as its male-biased ratio, relatively late flowering and seed production time hamper the cultivation of this plant. The development of efficient biotechnological platforms for better cultivation and an improved production cycle is a necessity for farmers cultivating the plant. In the last 20 years, many efforts have been made for *in vitro* cultivation of jojoba by applying different molecular biology techniques. However, there is a lot of work to be done in order to reach satisfactory results that help to overcome cultivation problems.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

- [1] **Gad HA, Roberts A**, Hamzi SH, Gad HA, Touiss I, Altyar AE, Kensara OA, Ashour ML. Jojoba Oil: An Updated Comprehensive Review on Chemistry, Pharmaceutical Uses, and Toxicity. *Polymers (Basel)*. 2021; 24;13(11):1711.
- [2] Al-Obaidi JR, Halabi MF, AlKhalifah NS, Asanar S, Al-Soqeer AA, Attia MF. A review on plant importance, biotechnological aspects, and cultivation challenges of jojoba plant. *Biol Res*. 2017 Aug 24;50(1):25.
- [3] Kar A. Desertification paradigms and measurement in Indian context. *Environment, People and Development: Experiences from Desert Ecosystem (Ed.)* -M.K. Gaur and P.C. Moharana. New India Publishing Agency, New Delhi. 2014; 17-55.
- [4] Abobatta WF. Overview of *Simmondsia chinensis* (Jojoba shrubs) cultivation and propagation methods. *Agriculture Research and Technology*. 2019; 19(2):556089.
- [5] Bala R, Laura JS, Beniwal VS. Direct adventitious shoot bud regeneration and ex vitro rooting in leaf explants of female *Simmondsia chinensis* (Link) Schneider- an important industrial shrub. *Asian Journal of Microbiology Biotechnology and Environmental Science*. 2019; 21: 448-454.
- [6] Osman HE, Abohassan AA. Introducing Jojoba in the Arabian Desert: Agronomic performance of nine jojoba clones selected in Makkah Area in Northern and Western Saudi Arabia. *International Journal of Theoretical Applied Science*. 2013; 5: 37-46.
- [7] Bala R, Laura JS, Beniwal VS. In vitro propagation of female *Simmondsia chinensis* (Link) Schneider—a Thar Desert shrub. *Annals of Biology*. 2020; 36:51-55.
- [8] Gentry HS. The natural history of Jojoba (*Simmondsia chinensis*) and its cultural aspects. *Economic Botany*. 1958; 12: 261-295.
- [9] Botti C, Franck N, Prat L, Carrasco O, Canaves L. Características botánicas. In: La Jojoba (*Simmondsia chinensis* (Link) Schneider). Serie Ciencias Agronomicas No. 5 Facultad de Ciencias Agrarias. Universidad de Chile, Santiago. 2001; 5.
- [10] Weiss EA. Crambe, niger and jojoba. In: *Oilseed Crops*. Longman, London, UK. 1983; pp. 507-527.
- [11] Bala R, Laura JS. Effect of various soil medium on seed germination of *Simmondsia chinensis* (Link) Schneider (jojoba) under in vivo conditions. *International Journal of Pharm and Biological Science*. 2015; 6(B): 77-81.
- [12] Zaher FA, El Kinawy OS, El-Haron DE. Solvent extraction of jojoba oil from pre-pressed jojoba meal. *Grass Aceites*. 2004; 55: 129-134.
- [13] Bala R, Laura JS. Micropropagation of *Simmondsia chinensis* (link) Schneider: a review on the regeneration potential of different explants. *International Journal of Current Research*. 2013; 5: 3610-3617.
- [14] Agrawal V, Sharma K, Gupta S, Kumar R, Prasad M. Identification of sex in *Simmondsia chinensis* (jojoba) using RAPD markers. *Plant Biotechnology Reports*. 2007; 1: 207-210.
- [15] Reddy MP, Chikara J. Biotechnology advances in jojoba Deserts and Desertification 12 (*Simmondsia chinensis*). In: Ramawat, K.G. (Eds.). *Desert plants: Biology and Biotechnology*, Springer-Verlag, Berlin, Heidelberg. 2010; pp. 407-422.
- [16] Ranzato E, Martinotti S, Burlando B. Wound healing properties of jojoba liquid wax: an *in vitro* study. *Journal of Ethnopharmacology*. 2011; 134: 443-449.
- [17] Guirguis OW, Abd Elkader MFH, Nasrat AA. Enhancing antimicrobial activity for chitosan by adding jojoba liquid wax. *Material Letters*. 2013; 93: 353-355.
- [18] Undersander DJ, Oelke EA, Kaminski AR, Doll JD, Putnam DH, Combs SM, Hanson CA. Jojoba: Alternative field crops manual, University of Wisconsin-Extension, Cooperative Extension. 1990.
- [19] Agrawal V, Prakash S, Gupta SC. Effective protocol for in vitro shoot production through nodal explants of *Simmondsia chinensis*. *Biologia Plantarum*. 2002; 45: 449-453.
- [20] Sharma SK, Singh AP. Pharmacognostical evaluation of roots of *Simmondsia chinensis* (Link) Schneider. *International Journal of Pharmaceutical Science and Drug Research*. 2011; 3: 323-326.
- [21] Morrissey H, Van R, Weston B, Oliver M. Jojoba: Farm Level Analysis and Market Assessment. ABARE report prepared for the Murray-Darling Basin Commissions. 1996.

- [22] Yermanos DM. Jojoba- a potentially valuable species in the control of desertification. Proceedings of the Conference on Alternative Strategies for Desert Development and Management, 31 May-10 June 1977, United Nations Institute for Training and Research, Sacramento, California, USA. Agriculture. 1982; 2: 374-381.
- [23] Aftab F, Akram S, Iqbal J. Estimation of fixed oils from various explants and *in vitro* callus cultures of jojoba (*Simmondsia chinensis*). Pak Journal of Botany. 2008; 40: 1467-1471.
- [24] Shrestha MK, Peri I, Smirnoff P, Birk Y, Golan-Goldhirsh A. Jojoba seed meal proteins associated with proteolytic and protease inhibitory activities. Journal of Agriculture Food Chemistry. 2002; 50: 5670-5675.
- [25] Hosseini FS, Hassani HS, Arvin MJ, Baghizadeh A, Nejad GM. Sex determination of jojoba (*Simmondsia chinensis* cv. Arizona) by random amplified polymorphic DNA (RAPD) molecular markers. African Journal of Biotechnology. 2011; 10: 470-474.
- [26] Bala R, Laura JS, Beniwal VS. Large scale production of female plants of *Simmondsia chinensis* (Link) Schneider through synthetic seed technology. Plant Cell Biotechnology and Molecular Biology. 2020b; 21: 47-53.
- [27] Spencer GF, Plattner RD, Miwa T. Jojoba oil analysis by high pressure liquid chromatography and gas chromatography/mass spectrometry. J. Am. Oil Chem. Soc. 1977; 54:187-189.
- [28] Khairi MMA. Genetics and Breeding of Jojoba [*Simmondsia chinensis* (Link) Schneider]. In Advances in Plant Breeding Strategies: Industrial and Food Crops; Al-Khayri, J.M., Jain, S.M., Johnson, D.V., Eds.; Springer: Cham, Switzerland, 2019; Volume 6, pp. 237-276.
- [29] Li TSC. Medicinal Plants: Culture, Utilization, and Phytopharmacology; Technomic Pub. Co.: Lancaster, PA, USA, 2000; 517p.
- [30] National Research Council (U.S.). Advisory Committee on Technology Innovation. Ad Hoc Panel. In Jojoba: New Crop for Arid Lands, New Raw Material for Industry; National Academy Press: Washington, DC, USA, 1985; 102p.
- [31] Wisniak J. The Chemistry and Technology of Jojoba Oil; American Oil Chemists' Society: Champaign, IL, USA, 1987; 272p.
- [32] Habashy RR. et al., Anti-inflammatory effects of jojoba liquid wax in experimental models. Pharmacol. Res. 2005; 51: 95-105.
- [33] Matsumoto Y. et al., Acute Effects of Transdermal Administration of Jojoba Oil on Lipid Metabolism in Mice. Medicina. 2019; 55: 594.
- [34] Al-Obaidi JR, Halabi MF. et al., A review on plant importance, biotechnological aspects, and cultivation challenges of jojoba plant. Biol. Res. 2017; 50: 25.
- [35] Pazyar N, Yaghoobi R, Ghassemi MR, Kazerouni A, Rafeie E, Jamshyadian N. Jojoba in dermatology: A succinct review. G. Ital. Dermatol. Venereol. 2013; 148: 687-691.
- [36] Ranzato E, Martinotti S, Burlando B. Wound healing properties of jojoba liquid wax: An in vitro study. J. Ethnopharmacol. 2011; 134: 443-449.
- [37] Bhatia VK, Chaudhry A, Sivasankaran GA, Bisht RPS, Kashyap M. Modification of jojoba oil for lubricant formulations. J. Am. Oil Chem. Soc. 1990; 67: 1-7.
- [38] Miwa TK. Structural determination and uses of jojoba oil. J. Am. Oil Chem. Soc. 1984; 61: 407-410.
- [39] Quattrocchi U. CRC World Dictionary of Medicinal and Poisonous Plants: Common Names, Scientific Names, Eponyms, Synonyms, and Etymology; CRC: Boca Raton, FL, USA, 2012.
- [40] Ashour M.L. et al., *Simmondsia chinensis* (Jojoba): A comprehensive pharmacognostic study. J. Pharmacogn. Phytochem. 2013; 2: 97-120.
- [41] Kramer JKG, Sauer FD, Pigden WJ. High and Low Erucic Acid Rapeseed Oils: Production, Usage, Chemistry, and Toxicological Evaluation; Academic Press: New York, NY, USA, 1983; 582p.
- [42] Van Boven M, Daenens P, Maes K, Cokelaere M. Content and composition of free sterols and free fatty alcohols in jojoba oil. J. Agric. Food Chem. 1997; 45: 1180-1184.
- [43] Van Boven M, Holser R, Cokelaere M, Flo G, Decuyper E. Gas chromatographic analysis of simmondsins and simmondsin ferulates in jojoba meal. J. Agric. Food Chem. 2000; 48:4083-4086.
- [44] Van Boven M. et al., Identification of 4,5-didemethyl-4-Oalpha-D-glucopyranosylsimmondsin and pinitol alpha-D-galactosides in jojoba seed meal (*Simmondsia chinensis*). J. Agric. Food Chem. 2001; 49: 4278-4283.

- [45] Busson-Breyse J, Farines M, Soulier J. Jojoba wax: Its esters and some of its minor components. J. Am. Oil Chem. Soc. 1994; 71: 999.
- [46] Tank Chintankumar J, Borkhataria Chetan H, Baria Ashok H, Patel Rakesh P, Tamizharasi S, Sureja DK, Patel ID, Parmar GR. Formulation and evaluation of aceclofenac loaded maltodextrin based proniosome. Int. J. ChemTech Res. 2009; 1: 567–573.
- [47] Graille J, Pina M, Ploch D. Routine analysis of jojoba wax fatty acids and alcohols by single column capillary GC. J. Am. Oil Chem. Soc. 1986; 63: 111–116.
- [48] Culling CFA. Handbook of Histopathological and Histochemical Techniques: Including Museum Techniques, 3rd ed.; Butterworth-Heinemann: Oxford, UK, 2013. 26.
- [49] Abdel-Mageed WM, Bayoumi SA, Salama AA, Salem-Bekhit MM, Abd-Alrahman SH, Sayed HM. Antioxidant lipoxygenase inhibitors from the leaf extracts of *Simmondsia chinensis*. Asian Pac. J. Trop. Med. 2014; 7S1: S521–S526.
- [50] Abdel-Mageed WM, Bayoumi SA, Al-Wahaibi LH, Li L, Sayed HM, Abdelkader MS, El-Gamal AA, Liu M, Zhang J, Zhang L. et al., Noncyanogenic Cyanoglucoside Cyclooxygenase Inhibitors from *Simmondsia chinensis*. Org. Lett. 2016;18: 1728–1731.
- [51] Landis PS, Craver RH, Barton DE. Pyrolysis studies with jojoba oil. J. Agric. Food Chem. 1992; 40: 456–457.
- [52] Landis PS, Craver RH. Solubility of jojoba oil in organic solvents. J. Am. Oil Chem. Soc. 1984; 61: 1879–1880.
- [53] Bower DI. An Introduction to Polymer Physics; Cambridge University Press: Cambridge, UK, 2002; 444p. 31. Wisniak, J.; Liberman, D. Some physical properties of *Simmondsia* oil. J. Am. Oil Chem. Soc. 1975; 52: 259–261.
- [54] Knoepfler NB, Vix HLE. Vegetable Oils, Review of Chemistry and Research Potential of *Simmondsia Chinensis* (Jojoba) Oil. J. Agric. Food Chem. 1958; 6: 118–121.
- [55] Wisniak J. Potential uses of jojoba oil and meal—A review. Ind. Crop. Prod. 1994; 3:43–68.
- [56] Shani A. Functionalization at the double bond region of jojoba oil: I. bromine derivatives. J. Am. Oil Chem. Soc. 1981; 58: 845–850.
- [57] Shani A. Functionalization at the double bond region of jojoba oil: II. Diels-alder adducts of jojobatetraene. J. Am. Oil Chem. Soc. 1982; 59: 228–230.
- [58] Wisniak J, Alfandary P. Geometrical Isomerization of Jojoba Oil. Ind. Eng. Chem. Prod. Res. Dev. 1975; 14: 177–180.
- [59] Galun AB, Grinberg S, Kampf A, Shaubi E. Oxidation and halogenation of jojoba wax. J. Am. Oil Chem. Soc. 1984, 61, 1088–1089.
- [60] Galun AB, Shaubi E. Thermal isomerization of jojoba wax. J. Am. Oil Chem. Soc. 1984; 61: 564–569.
- [61] Wisniak J, Holin M. Hydrogenation of Jojoba Oil. Ind. Eng. Chem. Prod. Res. Dev. 1975; 14: 226–231.
- [62] Simpson TD, Miwa TK. X-ray study of hydrogenated jojoba wax. J. Am. Oil Chem. Soc. 1977; 54: 54.
- [63] Wisniak J, Alfandary P. Sperm Whale Oil Replacements from Halogenation of Jojoba Oil. Ind. Eng. Chem. Prod. Res. Dev. 1979; 18: 358–364.
- [64] Hagemann JW, Rothfus JA. Oxidative stability of wax esters by thermogravimetric analysis. J. Am. Oil Chem. Soc. 1979; 56: 629–631.
- [65] Meier L, Stange R, Michalsen A, Uehleke B. Clay jojoba oil facial mask for lesioned skin and mild acne—results of a prospective, observational pilot study. Forsch. Komplementmedizin. 2012; 19: 75–79.
- [66] Lovell CR. Plants and the Skin; Blackwell Scientific Publications: Oxford, UK, 1993; 272p.
- [67] Baccouch N, Ben Salah H, Belhadj S, Hentati O, Abdennabi R, Gharsallah N, Elfeki A. Ayedi M, Allouche N. Chemical characterization and biological activities of *Simmondsia chinensis* (Link) C. K. Schneid seeds oil. Cell. Mol. Biol. 2018, 64, 11–16.
- [68] Belhadj S. et al., Beneficial Effect of Jojoba Seed Extracts on Hyperglycemia-Induced Oxidative Stress in RINm5f Beta Cells. Nutrients. 2018; 10, 384.
- [69] Belhadj S. et al., Anorexic and metabolic effect of jojoba: Potential treatment against metabolic syndrome and hepatic complications. Nutr. Metab. 2020; 17: 24.

- [70] Clarke JA, Yermanos DM. Effects of ingestion of jojoba oil on blood cholesterol levels and lipoprotein patterns in New Zealand white rabbits. *Biochem. Biophys. Res. Commun.* 1981; 102: 1409–1415.
- [71] Abou-Zeid SM, Tahoun EA, AbuBakr HO. Ameliorative effects of jojoba oil on fipronil-induced hepatorenal- and neurotoxicity: The antioxidant status and apoptotic markers expression in rats. *Environ. Sci. Pollut. Res.* 2021.
- [72] Garti N, Shevachman M, Shani A. Solubilization of lycopene in jojoba oil microemulsion. *J. Am. Oil Chem. Soc.* 2004; 81: 873–877.
- [73] Shevachman M, Shani A, Garti N. Formation and investigation of microemulsions based on jojoba oil and nonionic surfactants. *J. Am. Oil Chem. Soc.* 2004; 81: 1143–1152.
- [74] Schwarz JS, Weisspapir MR, Shani A, Amselem S. Enhanced anti-inflammatory activity of diclofenac in jojoba oil submicron emulsion cream. *J. Appl. Cosmetol.* 1996; 14: 19–24.
- [75] Thakur NK, Bharti P, Mahant S, Rao R. Formulation and characterization of benzoyl peroxide gellified emulsions. *Sci. Pharm.* 2012; 80: 1045–1060.
- [76] Nasr M. et al., Jojoba Oil Soft Colloidal Nanocarrier of a Synthetic Retinoid: Preparation, Characterization and Clinical Efficacy in Psoriatic Patients. *Curr. Drug Deliv.* 2017; 14: 426–432.
- [77] Shahin M, Abdel Hady S, Hammad M, Mortada N. Novel Jojoba Oil-Based Emulsion Gel Formulations for Clotrimazole Delivery. *AAPS PharmSciTech.* 2011; 12: 239–247.
- [78] Touitou E, Godin B. Skin nonpenetrating sunscreens for cosmetic and pharmaceutical formulations. *Clin. Dermatol.* 2008; 26: 375–379.
- [79] Geeta A, Sanju D, HariKumar SL. Natural Oils as Skin Permeation Enhancers for Transdermal Delivery of Olanzapine: In Vitro and In Vivo Evaluation. *Curr. Drug Deliv.* 2012; 9: 172–181.
- [80] Zhang G. et al., Inhalable Jojoba Oil Dry Nanoemulsion Powders for the Treatment of Lipopolysaccharide- or H₂O₂-Induced Acute Lung Injury. *Pharmaceutics.* 2021; 13: 486.
- [81] Nashy ESHA, Megahed MG, Abd El-Ghaffar MA. Preparation of Fat-Liquor Based on Jojoba Oil Under Phase Transfer Catalysis. *J. Am. Oil Chem. Soc.* 2011; 88: 1239–1246.
- [82] Santos EP, Dutra AJB, Oliveira JF. The effect of jojoba oil on the surface properties of calcite and apatite aiming at their selective flotation. *Int. J. Miner. Process.* 2015; 143: 34–38.
- [83] Di Berardino L, Di Berardino F, Castelli A, Della Torre F. A case of contact dermatitis from jojoba. *Contact Dermat.* 2006; 55: 57–58.
- [84] Mokhtari C, Malek F, Caillol S, Negrell C. Synthesis of Bio-Based Polyurethanes from Jojoba Oil. *Eur. J. Lipid Sci. Technol.* 2018; 120: 1700414.
- [85] Mokhtari C, Malek F, Manseri A, Caillol S, Negrell C. Reactive jojoba and castor oils-based cyclic carbonates for biobased polyhydroxyurethanes. *Eur. Polym. J.* 2019; 113: 18–28.
- [86] Daugherty PM, Sineath HH, Wastler TA. Industrial raw materials of plant origin. IV. A survey of *Simmondsia chinensis* (Jojoba). *Econ. Bot.* 1958; 12: 296–304.
- [87] Wisniak J. Chemistry and Technology of Jojoba Oil: State of the Art. In Sixth International Conference on Jojoba and Its Uses: Proceedings Beer-Shiva, Israel, 21–26 October 1984; American Oil Chemists' Society: Beer-Shiva, Israel, 1984.
- [88] Bisht RPS, Sivasankaran GA, Bhatia VK. Additive properties of jojoba oil for lubricating oil formulations. *Wear.* 1993; 161: 193–197.
- [89] Nasser R, Nassar A, Ahmed N. Jojoba Polymers As Lubricating Oil Additives. *Pet. Coal.* 2015; 57:120–129.
- [90] Abdelmoez W, Tayeb AM, Mustafa A, Abdelhamid M. Green Approach for Biodiesel Production from Jojoba Oil Supported by Process Modeling and Simulation. *Int. J. Chem. React. Eng.* 2016; 14: 185–193.
- [91] Sarojini G, Kannan P, Pravin G. Production of biodiesel from jojoba oil using ultra sonicator. *J. Environ. Biol.* 2019; 40: 802–806.
- [92] Kozliak E. Non-catalytic cracking of jojoba oil to produce fuel and chemical by-products. *Ind. Crop. Prod.* 2013; 43: 386–392.

- [93] Al Omari SAB, Hamdan MO, Selim MYE, Elnajjar E. Combustion of jojoba-oil/diesel blends in a small scale furnace. *Renew. Energy*. 2019; 131: 678–688.
- [94] Kaul S, Goyal HB, Bhatnagar AK, Gupta AK. Effect of ageing on quality of jojoba oil from Indian locations, *Industrial Crops and Products*. 2009; 29: 1: 102-107, ISSN 0926-6690, <https://doi.org/10.1016/j.indcrop.2008.04.014>.
- [95] **Bal R.** Jojoba-The Gold of Desert. *Deserts and Desertification*. Inter open. 2021; 1-12. DOI: <http://dx.doi.org/10.5772/intechopen.99872>.
- [96] Malhotra EV, Mali SC, Bansal S. *et al.*, An efficient and reproducible cryopreservation protocol for sustainable conservation of Jojoba (*Simmondsia chinensis*). *Sci Rep*. **2026**; **16**, 1356. <https://doi.org/10.1038/s41598-025-30951-0>.
- [97] Jojoba Oil Market to Reach \$272.4 Million by 2026 - dermascope.
- [98] Zhu X, Zhu M. et al., Genome-wide analysis of the CHIA gene family and functional characterization of *ScCHIA1* under cold and osmotic stress in jojoba (*Simmondsia chinensis*). *Plant Science*. **2026**; 368,, 113130.
- [99] Ghareeb RY, Eid SM, Omran SA. Open-field evaluation of jojoba (*Simmondsia chinensis*) oil emulsion and its seed cake for biological control of root-knot nematode (*Meloidogyne incognita*) in hybrid watermelon (Giza type). *Pakistan Journal of Nematology*. **2026**; 44(1): 48-57.
- [100] Alotaibi SS, Elseehy MM. et al., Transcriptome Analysis of Jojoba (*Simmondsia chinensis*) during Seed Development and Liquid Wax Ester Biosynthesis. *Plants*. 2020' 9: 588; doi:10.3390/plants9050588.