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Jojoba - The Gold of Desert

Raman Bala

Abstract

Jojoba [*Simmondsia chinensis* (Link) Schneider] is evergreen, perennial and drought resistant shrub belongs to the family of *Simmondsiaceae*. 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. 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. The main uses of liquid-wax in various industries like cosmetics, pharmaceuticals, petrochemicals and lubricants. It is a potential seed oil crop for desert region so it is well known as the gold of desert. The main purpose of this chapter is to review the complete information about this plant so that it can produce and utilized maximally. Moreover, the review focuses on biology, biogeography, physico-chemical properties of jojoba oil and propagation techniques of the plant of desert regions.

Keywords: Desertification, jojoba, liquid-wax, gold of desert, propagation, unique

1. Introduction

Desertification is recognized as a major threat to global biodiversity and a burning issue to environment today. The desert land starts to degrade its chemical, physical and biological productivity. 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].

India has developed Biodiversity Action Plans to counter its causes and their effect, management and conservation of endangered flora and fauna. Various environmental organizations focus on restoration of such land to control the desertification mainly in dry land areas. 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. 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 [2]. The commercial plantation of jojoba is encouraging mainly in Thar Desert in India. It is also known as gold of desert because it has valuable industrial application and easily grows on desert land [3].

Jojoba plantations played a vital role in combating edge effects of desertification and improve soil quality and restores land quality [4]. It is a potential oil-seed crop

and helps in soil conservation, landscaping, open natural range lands and national parks. 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 replenisher 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 [5].

Jojoba [*Simmondsia chinensis* (Link) Schneider] is a potential seed oil plant, belonging the family *Simmondsiaceae* that have played role in combating edge effects of desertification in the Thar Desert in India [6]. There are huge tracts of arid and semi arid lands in India where it has the potential to grow as an important commercial crop. 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. Also, 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.

2. Biology

The other names of jojoba are hohoba, coffee berry, goat nut, deer nut, pig nut, coffee bush and lemon leaf. The first taxonomic status of this species appeared in 1822, when Johann Link named it as *Buxus chinensis* but later in 1844, it was changed to *Simmondsia californica* by Thomas Nuttall. In 1912, the Austrian botanist, Camillo Karl Schneider, renamed it as *S. chinensis* [7]. In 1897, a European botanist, Van Tieghem, proposed the creation of a new family *Simmondsiaceae*, with *Simmondsia* being the only genus containing a single species. According to the International Rules of Botanical Nomenclature, the specific name *chinensis* had first been given to jojoba that became *S. chinensis* (Link) Schneider [8].

The plant of jojoba is leafy, xerophytic, woody evergreen, dioecious in nature with small multi-stemmed that grows to a height of 0.5–1 m in the wild, occasionally to 6 m tall with taproots to 12 m long (**Figure 1a, b**). The natural life span appears to be over 100 years and may exceed 200 years [7].

Leaves are simple, opposite, pale green or yellowish green, oblong-ovate, rounded at both ends and leathery. The leaf apparently lives for two to three seasons, depending on moisture and shade conditions. They are 2.5 to 3.5 cm long, 0.5 to 1.5 cm wide and contain special tissue with a high concentration of phenol compounds [7].

Flowers are apetalous, unisexual and dioecious in nature. The flowers are pollinated by wind. The male flowers are yellow, larger, and occur in clusters with 10–12 stamens per flower while female flowers are small, usually solitary in the axils or in clusters at the nodes, pale green with 5 greenish sepals, soft and hairy (**Figure 1c, d**) [9].

It has also been reported that male plants have a smaller canopy than female plants. Plant has growing buds at axils position, actively grows and developing into a flower in the blooming season. It was noticed that these flowers buds developed at every second or third nodal position of the stem. Further, these nodal buds differentiated and grow into flowers [10].

The plant has a tap-root system. The root of mature plants can be 15–25 m below the soil surface, with substantial parallel laterals and secondary roots, giving an ability to draw moisture from the soil. Thus, allowing the plants to survive and grow where most of the other plants wither and die [11].



Figure 1.
 Morphological characteristics of male, female, fruit and seeds *S. chinensis* (a) *S. chinensis* shrub (6 months)
 (b) mature plant (c) female flower (d) male flowers (e) immature seed (f) mature seeds.

Fruit is a green and smooth cylindrical capsule of about 2 cm length, somewhat resembling an acorn shape. The calyx of flowers is persisting with dehiscent nature and contains ovules (1–3) attached to the placenta of capsule. The capsule develops in three months and matures in five to six months. Finally, capsule splits and seeds drop out through three sutures [8].

Seeds are peanut or acorn shaped, with a small pointed apex, and flattened base (**Figure 1e, f**). The color of seed is dark brown to black with smooth texture

and 1–2.5 cm in long. The weight of one hundred seed can vary from 40 to 80 gm, occasionally much higher, but it is more constant for seeds from wild plants in a specific location [7].

In desert regions, plants used for revegetation as it can survive as harsh arid environmental conditions as in Rajasthan, India. The jojoba plant has potential as a soil-stabilizing nature due to its low nutrient requirements, deep root system, drought resistant, longevity and low susceptibility to fire. Jojoba is a potentially valuable industrial plant species for the control of desertification [6]. As properties oil of jojoba is same as oil of sperm whale. Therefore, more production of jojoba oil has been considerably reduced the prey of sperm whale which is now a endangered aquatic animal. The cultivation of one hectare jojoba produced oil is equal to oil derived from 124 sperm whales. Moreover, the intercropping of jojoba crop in desert land played a role of eco-friendly nature and combating desertification process [8].

3. Biogeography

The natural area of wild jojoba comprises approximately 161,000 km² between latitudes 23° and 34° North of latitude and between 109° and 118° West of longitudes. This shrub is native to Sonoran desert in Southern Arizona, Southern California and North-western Mexico. Now, it is being cultivated in Mexico, United States of America, Argentina, Australia, Brazil, Costa Rica, Egypt, Haiti, Israel, Paraguay and South Africa. It is used as an ornamental shrub throughout the Southern United States [7]. The plant survives in warm temperate desert to tropical desert forest. It tolerates full sun and temperatures ranging from 0 to 47°C. Mature shrubs tolerate temperatures as low as –10°C, but seedlings are sensitive to light frosts just below freezing. The rainfall 375 to 450 mm annually is considered optimum for its growth. Optimum growth occurs in a temperature range of 27–36°C, but plants can withstand very high temperature. A daily range of –1 to 50°C has been recorded in the Mexican desert habitat, but above 50°C is believed to suppress growth, although not lethal [11].

It can be grown in all types of soils which are well drained and have an average pH between 7 and 8.5. The plants has high growth in the desert soil with small amount of farm yard manure [12]. But the basic requirement is that soil must not be liable to water logging. Also, it can be grown on marginal and wasteland due to tolerance of extreme range of temperature from –5 to 54°C [13].

4. Physico-chemical properties of oil

Jojoba seeds contain about 50% oil content with a range 44 to 59% which is light gold colored and odorless liquid wax ester. Chemically, jojoba oil is a liquid wax not oil because it has neither a liquid fat nor triglycerides as all other vegetables oils. Actually, jojoba liquid wax is composed of long chain (C₂₀–C₂₂) of fatty acids and fatty alcohols with two unsaturated bonds which make the oil susceptible to many different types of manipulations. The composition of oil accounts for its extreme shelf-life stability and extraordinary resistance to high temperatures as compared with true vegetables oils. It is natural, pure and stable due to high resistance to oxidation and can be stored for years without being rancid [14].

The extracted oil is relatively pure, non-toxic, biodegradable and resistant to rancidity. It is unique among vegetable oils, as sperm whale oil is unique among animal oils [15]. Jojoba oil can be classified as non-toxic substance, and used safely

for external applications on healthy skin and wounds. The physical properties of liquid-wax involve high viscosity, high flash and fire point, high dielectric constant, high oxidative stability and low volatility which makes it usable as lubricant in high pressure machinery and electric insulators. The viscosity index of jojoba oil is much higher than that of petroleum oil [7].

Jojoba oil has unusual stability, remarkably pure and need not be refined for use as transformer oil or as a lubricant for high speed machinery or machines operating at high temperatures. It used as an industrial oil for improver of lubrication power of oil of cars, airplanes and various other machines and also as a surfactant improver of paints, varnishes, plastics, waxes for better performance. Therefore, future need of huge quantities of jojoba oil for lubricant industry, especially for cars and aeroplanes but oil produced in present would not be sufficient to meet all needs of various industries.

The melting point of jojoba oil is approximately 10°C and the iodine value is nearly 80. The evaporating point of jojoba oil is 315°C which is highest in the vegetable oils. As is free from glyceride so there no need for its retiming and easily modified via hydrolysis, hydrogenation, halogenation, sulfurization, phosphosulfurization and ozonization techniques [8].

The jojoba oil does not contain sulfur therefore, mainly used in various industries sectors. The stability of oil is high and makes its very useful in the electronic and computer industries. It is also suitable for process of sulfurization to produce high quality of lubricant and rubber like material used for making ink and linoleum. Other used of jojoba oil for making plasticizers, candles, detergents and fire retardants [16].

Jojoba has potential applications in cosmetics, pharmaceutical industries, plastic industries, leather industries and bio-fuel industry. The liquid wax and its derivatives have potential in a wide range of applications in cosmetics such as lipsticks, face creams, skin fresheners, winter care lotions, soaps, shampoos and moisturizers [17].

Liquid-wax is generally used in folk remedies for renal colic, sunburn, hair loss, headache and sore throat. The oil prevents rashes and wrinkles formation on the skin if used as a night cream. It is best for hair therapy as it keeps hairs smooth and silky with a shine and also prevents hair fall-out [18].

It has wound healing properties, anti-inflammatory activity, anti-microbial activity insecticidal, antifeedant and antifungal activities. It can be classified as non-toxic substance, and used safely for external applications on healthy skin and wounds burnt skin and to remove stretch marks [19]. Also, the wax resembles human sebum and can help dry and oily skin. It penetrates into skin rapidly without leaving any traces of oil within only a few seconds as it is a straight unsaturated ester chain of fatty alcohols and fatty acids. It is used for massage because of soothing and relaxing nature and gives relief in pain of body [20].

It has no cholesterol or triglycerides and therefore can be used as low calorie edible oil [20]. Indigenous Americans and Indians used jojoba seeds and oil for cooking, hair care and for medicinal treatments such as poison ivy, sores, wounds, colds, cancer and kidney malfunction [21]. Jojoba oil, known as the sperm whale of the desert is almost identical to the whale oil, commonly known as spermaceti [22]. Jojoba oil was heralded as being able to fill this gap because of its similar chemical properties.

Jojoba also had environmental appeal as it is produced from a relatively common plant resource rather than an endangered animal species [23]. Jojoba oil is a suitable coating for some medicinal preparations, stabilizer of penicillin products and inhibitor to growth of tubercle bacilli and anti-foaming agents. It serves as cutting and grinding oil or additive to other lubricants and is suitable as transformer oil [24].

Jajoba 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 is suitable for vegetable oil [25]. The jajoba meal extract has high 30–35% protein content and major proteins are albumins (79%) and globulins (21%) [26]. 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 [27].

Jajoba 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 [28].

5. Agronomy

The review of this content has led to greater understanding of the classic farming requirements for jajoba. Jajoba has the distinction of being the commercial crop successfully in desert of Rajasthan, India. 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. Soil texture is an important parameter for best growth in sandy and decomposed rocky soil. Even if the fertility of soil is marginal, jajoba is still able to produces well without use of fertilizers.

The irrigation system well established for jajoba 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. The root system should reach the level of aquifer thus enabling sufficient growth for seed production without supplemental watering.

Jajoba 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 jajoba crop at commercial scale. The need of jajoba growers for the successful commercialization depends upon selection of high yields germplasm and their further multiplication [29].

Propagation of jajoba crop is through direct seeding, seedlings, rooted cutting and plantlets produced from tissue culture techniques. 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 [29].

When commercial plantation rose through direct seeding, about more than 50% seedlings are males. But the requirement of male population is only 10% seedlings. 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. For commercial plantation with 90% female plants, leaving the 10% male plants to produces adequate pollen for all the female flowers. However, only the female plants gives the valuable seeds and requires more population in a commercial field [30].

Centre for Jatropha Promotion and Biodiesel (CJP) is a Global Jajoba World which focuses on commercialization of entire jajoba in arid and semi-arid regions of India. In Bikaner district Rajasthan of India, the commercial plantation raised through the rooted cutting of high yielding germplasm. 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, jajoba crop produced an economically useful yield after four or fifth years of plantings [7].

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. 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 [31].

The commercial plantations of jojoba raised successfully in Bikaner district of Rajasthan, India, shown in **Figure 2**. Naturally, flowering season of crops occurs in February to March and field image taken by author in 2019, Bikaner, Rajasthan, India (**Figure 3**). The collections of seeds manually and processed by labourers in farmhouse as shown in **Figure 4**. The jojoba meal or cake used as fertilizers in a field, image taken by author as in **Figure 5**.



Figure 2.
Well establishment of jojoba plantation in Bikaner, Rajasthan, India.



Figure 3.
Flowerings of female jojoba plant in a field of Bikaner, Rajasthan, India.



Figure 4.
Collection and processing of jojoba seeds in Bikaner, Rajasthan, India.



Figure 5.
Jojoba meal after oil removing process in farmhouse of Bikaner, Rajasthan, India.

The commercial plantation of jojoba manages by CJP through advanced crop practices adjustable to local soil quality, weather conditions, pest and disease control during frosting time. Therefore, the CJP developed a improved technology to ensures high yielding germplasm, crop management, irrigation system, fertilizers requirement, harvesting techniques, post-harvesting techniques and further grading-up process [31].

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. 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 [31].

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. 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. However, the CJP keep watching on research towards jojoba breeding techniques and collecting the useful information related to jojoba cultivation methods. The enhanced variety of jojoba with regards of seed yield and oil yield with enhanced jojoba cultivation techniques may ensures early flowering and fruiting into profitable production of oil crop.

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. 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. In India the development of jojoba cultivation including crop management, drip irrigation system and cost of production of one kilogram seeds is 0.5 \$. This low cost of production in the country as compared to other oil seed crop gives it a competitive edge [31].

According to agronomist, the plantation of jojoba requires less water as compare to other oil seed crops in desert regions. 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. Also, the CJP can help to farmers to identifying the needs, opportunities and solution of local, regional and national markets values. For best farming system, the CJP directs to creating best business strategy for effective cultivation of jojoba.

6. Conclusion

Jojoba is a potential seed oil crop of industrial importance mainly grows in the Thar Desert of Rajasthan, India. The arid and semi-arid land of India are all set to usher in revolution in Indian agriculture with planned large scale cultivation of the exotic jojoba plant. Jojoba in the country is now being grown on area of about thousand hectares and the area is increasing every year. 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. 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.

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Author details

Raman Bala
Department of Environmental Science, Maharshi Dayanand University,
Rohtak, India

*Address all correspondence to: nandwalraman72@gmail.com

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