Indian J. Pl. Genet. Resources 4(2): 57-66, 1991

PERFORMANCE AND POTENTIAL OF JOJOBA IN THE INDIAN ARID REGIONS

Neelam Bhatnagar, D.C Bhandari, N.K.Dwivedi and R.S. Rana[1]

National Bureau of Plant Genetic Resources
Regional Station, Jodhpur 342-003 (Rajasthan)

Jojoba (Simmondsia chinensis *(Link.) Schneider) was introduced in India in sixties because of its adaptability in deserts and high economic potential mainly as a substitute to sperm whale oil. Since then, its perfromance in the experimental area has been observed for its survival and potential in the Indian arid region. The studies revealed great variation in the plant habit, form, growth pattern, reproductive potential and seed yield among and within various introduced accessions. Of them, EC 33198 introduced in the late sixties has been identified as suitable variety for this region.*

Jojoba (*Simmondsia chinensis* (Link.) Schneider) is an evergreen, hardy shrub native to the Sonoran desert of Mexico. It can withstand drought, tolerate salinity and has been reported to adapt to wide range of temperatures, rainfall and habitat conditions (Anon, 1975). Its suitability to areas where no agricultural crop can thrive along with its valuable liquid wax rich seeds render it potential, economicaly viable and an attractive agricultural investment for such areas (Bhatia and Gulati, 1981). The economic potential of jojoba was known in the early sixties, yet it received widespread attention only the chemical similarity between its oil and the sperm whale oil was ascertained coinciding with the placement of sperm whale in the endangered list (Princen, 1983). Since then, worldwide efforts have been put into the cultivation, breeding, harvesting and processing of jojoba.

BOTANY AND USES

Jojoba (pronounced as ho-ho-ba) also called as bushnut, bucknut, deernut, pignut, sheepnut, goat berry, coffee berry, wild

[1]National Bureau of Plant Genetic Resources, New Delhi 110 012

hazel or quinine plant is considered to be the only arid adapted species of widely distributed family, Buxaceae, though it is also considered to be a member of a unique monotypic family Simmondsiaceae (Brooks, 1978).

Jojoba is an evergreen, compact, perennial shrub with greyish green leaves and tap root system. In the past, its oil was used by native North American Indian tribes to treat sores, cure stomach problems and restore hair. As a food, seeds were used raw or roasted, ground with water and sugar to make various beverages, like a coffee substitute. Besides its similarity to sperm whale oil, the oil of jojoba has an added advantage of having fewer impurities, odourless nature, greater shelf life and thus has a great potential as a lubricant and chemical intermediate in industrial processes. The oil can be hydrogenated to form a hard, crystalline wax, to be used in manufacture of polish waxes, carbon paper, impregnated heat resistant paper containers. The reaction of oil with sulphur chloride to form a rubbery compound known as factice is used in varnishes, rubber, adhesives, etc. Owing to its remarkable resistance to degradation and odourless nature it has a wide potential in the pharmaceutical and cosmetic industry.

ORIGIN, DISTRIBUTION AND CULTIVATION

The origin of jojoba remains obscured, but its growth in natural stands has been noticed to be linked with winter-spring rains, thus indicating its origin in the Mediterranean type of climate along the Pacific coast (Brooks, 1978). At present, the widest distribution of jojoba is in the islands of Gulf of California, coastal Sonora in Mexico, the mountains around Salton sea basin, sourthern portions of San Diego, and Tucson in Arizona. The species extends from 600-1300 m. elevation above sea level on well drained dry slopes, mostly in areas receiving 19 to 50 cm annual rainfall.The topographical effects on micro-environmental conditions, particularly soil moisture, influence the distribution of jojoba. These effects are more pronounced during early seedling and flowering stages. Otherwise, the plant has a high degree of physiological tolerance to drought and high temperatures. However, during severe drought the leaves may be shed. Jojoba has a medium water requirement throughout the year (Sherbrooke and Hasse, 1974). In all habitats, including coastal and inland desert areas, plants remain physiologically active during the entire year reflecting its potential to maintain a positive carbon balance even under conditions of severe drought.

Jojoba has been extensively cultivated in many arid regions of the world resulting in its spread in over fifty thousand hectares of land worldwide mainly in Israel, Mexico, Costa Rica and Australia (Anon.

1975). Other countries with similar climates are already in the process of introduction and many countries including India have taken up its cultivation.

PLANT INTRODUCTION IN INDIAN ARID REGION

Jojoba was first introduced in Indian arid region in 1965 (Harsh *et al.*, 1987). Simultaneously, augmentation of jojoba from its native habitats was made by the National Bureau of Plant Genetic Resources, New Delhi and in the process several accessions were introduced mainly from USA. The prime objective was to assess their suitability under the Indian arid conditions at one of its Regional Stations at Jodhpur. This region is characterized by scanty and erratic rainfall concentrated in monsoon (July to September), winters devoid of rains, frequent droughts, high temperatures, intense sunshine, frost, high wind velocity, poor soil conditions viz., low content of organic matter and minerals coupled with soil salinity and alkalinity. The live plants of various accessions of jojoba being maintained at NBPGR Regional station, Jodhpur were raised from seeds obtained from different countries, mainly USA (Table 1) and those multipled from selections made in due course. In the early years of introduction, adaptability evaluation was the main criteria and the growth parameters were not recorded. But of late, these parameters, viz., morphology of the vegetative and reproductive parts, the flowering

Table 1. Accessions of jojoba introduced at NBPGR Regional Station, Jodhpur

Year	Number of Accessions		
	Introduced	Surviving (EC number)	
1966	1	1	(33204)*
1967	2	2	(33205*; 33198***)
1969	7	2	(52039*; 52040*)
1972	5	2	(99689*; 99690*)
1977	3	1	(124381)***
1980	9	1	(134349)**
1981	1	Nil	—
1983	2	Nil	—
1984	2	Nil	—
1985	1	Nil	—
1987	1	1	(171269)*
1988	7	6	(253492***; 267778*; 267779*; 267780***; 267781**; 267783*)
1989	4	4	(272472*; 272473**; 279585**; 279586*)
Total introduction	45	22	

* = Male, ** = Female, and *** = Male and Female.

and fruiting behaviour and the seed yield were recorded at periodic intervals on plants of various age groups. Attempts were also made to obtain hybrids between the highest yielding female accession identified and the various male accessions being maintained.

PLANT GROWTH AND HABIT

Observations of the initial growth rate of jojoba revealed it to be a slow starter with an average increase of only 5-20 cm per year. Striking variation in plant height was observed within and between accessions in the field. The variation, though evident in the early stages of plant growth was more conspicuous in the age group of 8-10 years. Among the various accessions introduced, the maximum number of plants of accession EC 33198 of different ages were available in the field. These plants were observed for studying the variation. Maximum variability in the plant height was observed in the age group of 9 years (Fig. 1). The variation was also observed in plant canopy in all the accessions. It ranged from 50 to 412 cm (Table 2). At the initial stages of plant growth the ratio of plant height to canopy was found to be 1:1 but at later stages it changed due to greater increase in canopy over height.

Plant habit ranged from tall erect to short bushy, with the greater representation of the latter with spheroid, compact and loose forms (Plate 1 A & B). Several environmental factors as plant density, light intensity, prunning, etc., affect the form of the bush. The branching pattern observed in all the accession was basically a main shoot of 15-20 cm supporting a number of primary, secondary and tertiary branches. The leaves, in general, are simple, greyish green, thick, leathery, coriaceous arranged in pairs on the primary, secondary and tertiary branches. Variation in leaf size, shape, colour, thickness and pubescence was observed. Such variations in the growth habit, form and leaf shape have also been recorded by Yermanos (1974) and Brooks (1978). However the variation occurs throughout the population in such a way that no distinct subspecies is recognizable.

FLOWERING AND FERTILIZATION

All plants of jojoba in the field are dioecious. Female flowers are pale green, usually single, while male flowers are small, yellow and in clusters. The flowers are borne on leaf axils. Normally, one flower on an alternate leaf axil develops into a seed while others remain dormant. However, flowering on all leaf axils has also been observed in a few plants. Flowering, in general,was observed in all surviving accessions at the age of 3-4 years in November-December and the fruits matured between April-May (Table 2). Approximately, 10 flowers per branch for female, and 20-30 clusters/branch for male flowers were observed. Flowering was mostly observed on peripheral tertiary branches. The

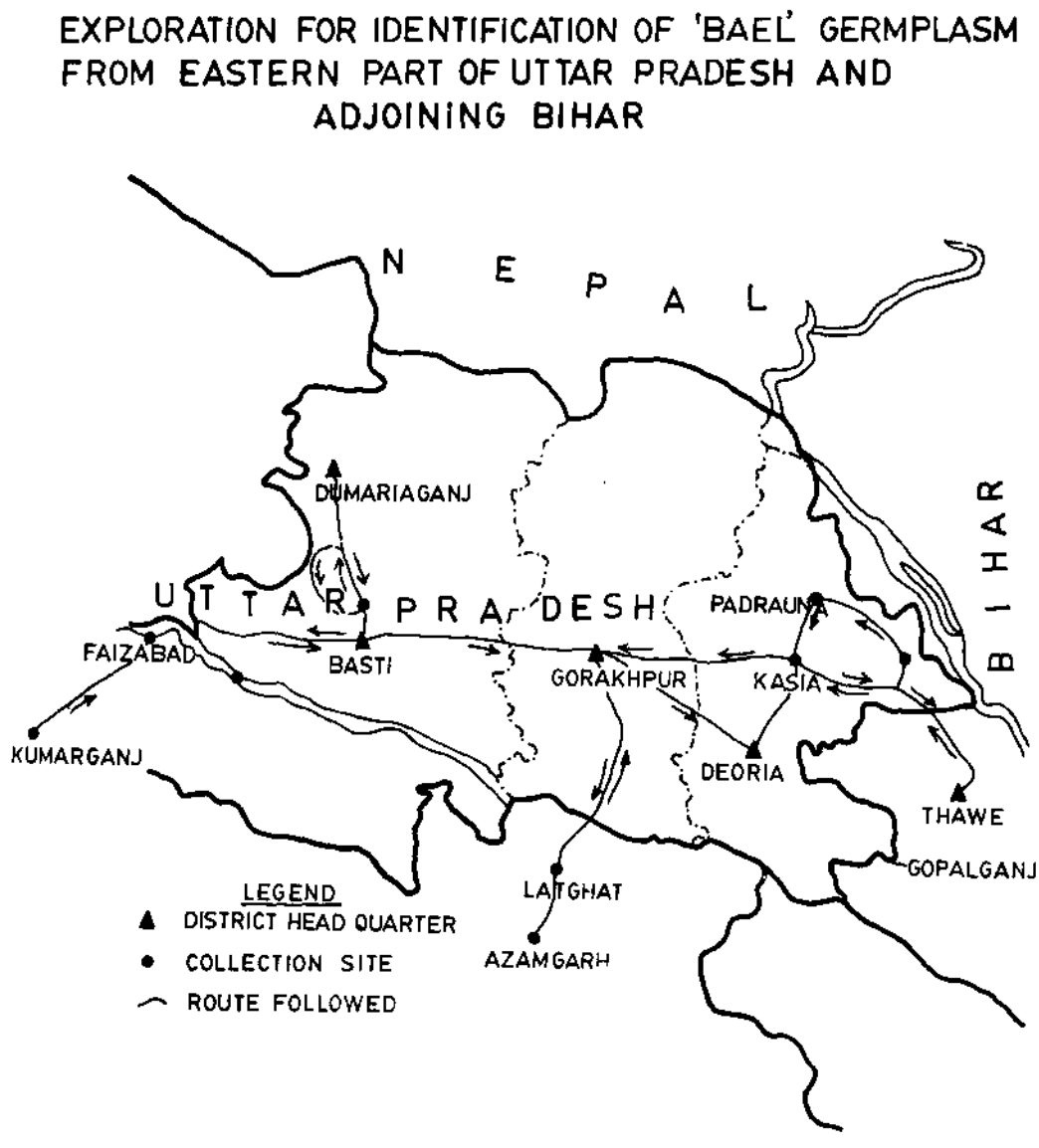

Fig. 1. Height of individual jojoba plants (EC 33198) of different ages.

Table 2. Some phenological observations on different accessions of jojoba plants of various age groups

Accession number	Year of trans-plantation	Plant height (cm)	Plant canopy X_1	Plant canopy X_2	First flowering	First fruiting
EC 33205	1967	200	297	318	1970	Nil (Male)
EC 33198	1970	232	412	397	1972	1974
EC 33198	1974	202	185	215	1978	1979
EC 33198	1976	160	158	153	1981	1982
EC 33198	1978	146	169	152	1982	1983
EC 33198	1982	93	100	96	1986	1986
EC 33198	1983	108	97	99	1986	1987
EC 33198	1984	69	65	58	1987	1987
EC 99690	1972	182	180	205	1977	1979
EC 99691	1972	150	205	158	1978	1979
EC 124381	1978	170	163	163	1985	1985
EC 134349	1982	90	50	88	1988	—

Plate I. Plant forms of jojoba. A. Bushy B. Erect

ovary is tricarpellary, but generally only one carpel develops into seed. Occasionally, more than one ovule develops to form 2-3 seeded fruits. Male plants flowered earlier to females. Also, in the population of different accessions, the number of male plants was higher than females. Pollen loss and reduction in seed yield was also observed. To avoid this, a number of planting patterns like alternate rows of male and female plants, transplantation of three saplings together and later removing the males were tried but no method could be standardized. Thus, the hand pollination by dusting the desired pollen on female flowers was practised to increase the pollen availability to female flowers. Male plants, however, tended to survive stresses at early stages more effectively than females as also observed in natural populations (Gentry, 1958). In Arizona, male plants were reported to outnumber females by more than 4 to 1 in natural stands. In California, the sex ratio was reported to be nearly equal. Yermanos (1977) concluded that the data collected on male-female ratio over the first three years of growth show that there is a significant deviation from a 1:1 ratio in favour of males. However, it has also been reported that if flowering data collection was continued for an additional year, this ratio moves closer to 1:1. Heavy flowering and fruiting was observed in plants when supplementary irrigation was applied at the onset of flowering.

SEED YIELD

The most common fruiting pattern in jojoba is of a single fruit on each alternate node (Plate II A). However, a few plants with tendency to develop more than one fruit per node have also been observed (Plate II B & C). Multiple flowering leads to the formation of such fruits as shown in Plate II D. This is a very desirable trait as these plants have great potential for enhancing the seed yield per plant and also facilitate harvesting (Yermanos, 1974). Vartiation in flowering in natural populations has also been reported in Arizona and California. While in the former, female flower buds remain dormant at every alternate node, in the latter flowering is observed at every node. This reduces the yield potential of Arizona stock. It is desirable to select the all node bearing stocks. Data on seed yield per plant as observed over the years in the field revealed that all accessions have fruited after 5-6 years (Table 2). Seed yield was only 50-200 g in the first few years of fruiting, which increased to 2-3 kg in plants of 8 years. Variability in seed yield per plant was noted in plants of same accession of the same age. Maximum fruit yield of 8.3 kg/plant was noted in accession EC 33198, which incidentally is also the earliest introduction in this region (21 years old) (Fig. 2). Fruits are usually acorn like capsules, bearing mostly one seed. However, 2, 3, or 4 seeded fruits have also been observed. Seed length varied from 1-1.5 cm.

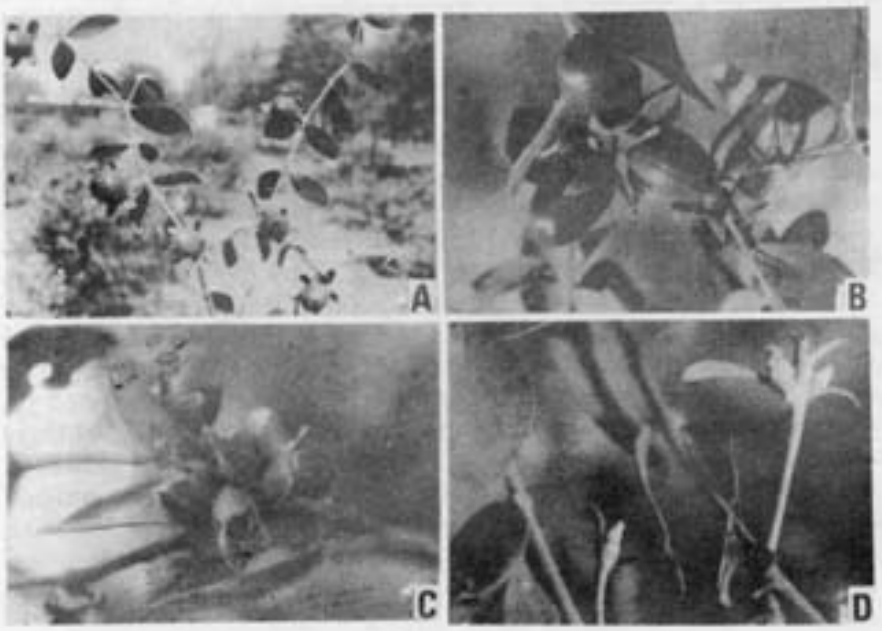

Plate II. Flowering and fruiting in jojoba. A. Fruiting at alternate nodes. B. and C. Fruits in clusters. D. Multiple female flowering.

PROMISING ACCESSIONS AND PLANT IMPROVEMENT

Among the accessions introduced, one female plant (EC 33198 from USA) was identified as the best seed yielding accession (Chopra and Mital, 1979).Thus, attempts were made to multiply the germplasm. The selected material of EC 33198 was used to obtain crosses with pollen of male plants of accessions EC 33204, 52039, 99690 and 99692 (all from USA) in the flowering season of 1979. The plant canopy was divided into four equal parts. Controlled pollination of the equal number of desired female flowers was carried out in the each of the four parts with pollen from the known male plants, making sure that no contamination occurred either before or after pollination. Flowers were monitored closely at weekly intervals to follow success of fruit formation. Some success was achieved and seeds collected. The plants raised from these seeds were found to perform better, flower earlier, i.e., within three years of establishment and produce bold seeds. The observations recorded on the plants obtained from crossed material are summarised in Table 3.

Table 3. Some phenological observations on crossed material of jojoba

Male accession crossed with female accession EC 33198	Year of transplanting	Plant height (cm)	Plant canopy X_1	Plant canopy X_2	First flowering	First fruiting
EC 33205	1982	176	183	192	1985	1985
EC 52039	1982	167	165	151	1985	1985
EC 99690	1982	133	154	150	1985	1985
EC 99692 (control)	1982	131	140	143	1985	1985

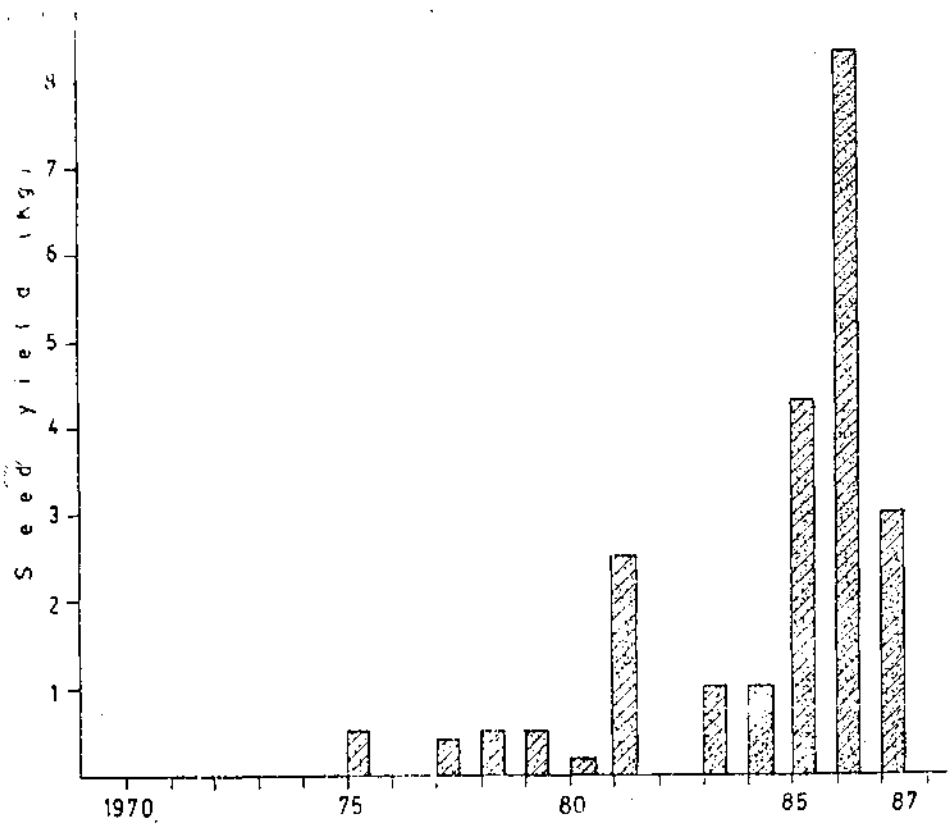

Fig. 2. Seed yield of an individual plant of jojoba, EC 33198 over years

CONCLUSIONS

The success of jojoba for the past two decades suggests its suitability especially of accession EC 33198 (ex USA) for the Indian arid region. However, information on its production potential, economic viability and returns, land utilization, market, etc. under different agroclimatic conditions needs to be collected. Though this work has been initiated in India, the results are yet to be consolidated. Therefore, careful investigation, planning and future strategies need to be formulated before mass-scale introduction of jojoba be carried out in wastelands or barren regions not fit for agricultural crops in Indian deserts. Work should also be done for early identification of sex by detailed cyto-chemical, biochemical or anatomical studies. Hybridization work must be given top priority as it would aid in production of high yielding varieties. Vegetative propagation and extraction and utilization of jojoba oil needs to be tried as it has direct relevance to the adoption of jojoba farming by the local farmers and agriculturists.

ACKNOWLEDGEMENTS

Authors are thankful to Shri T.A. Thomas, NBPGR, New Delhi and Shri D.P. Chopra, Ex. Officer-in-Charge, NBPGR Regional Station, Jodhpur for their keen interest, encouragement and facilities provided in this work.

REFERENCES

Anonymous. 1975. Under exploited tropical plants with promising economic value. National Academy of Sciences, Washington D.C. p 105-110.

Bhatia, V.K. and I.B.Gulati. 1981. Chemistry and utilization of oil of jojoba (*Simmondsia chinensis* Schneider). *Jour. Sci. & Industr. Res.* **40** : 45-50.

Brooks, W.H. 1978. Jojoba: A North American desert shrub; its ecology, possible commercialization and potential as an introduction into other arid areas. *Jour. of Arid Environments* 1: 227-236.

Chopra, D.P. and S.P. Mital. 1979. New plants for semi-arid zone of west Rajasthan. *Indian Fmg 28: 19-21.*

Gentry, H.S. 1958. The natural history of jojoba (*Simmondsia chinesis*) and its cultural aspects. *Econ. Bot.* **12**: 261-295.

Harsh, L.N., J.C Tewari,D.S. Patwal, G.L. Meena. 1987. Package of practices for cultivation of jojoba (*Simmondsia chinensis*) in arid zone. CAZRI Jodhpur, No. 32, 19 p.

Princen, L.H. 1983. New Oilseed crops on the horizon. *Econ. Bot.* **37**: 478-492.

Sherbrooke, W.C and E.F. Hasse. 1974. Jojoba : A wax producing shrub of the Sonoran desert. *In:* Literature review and annonated bibliography. Arid Lands Resource Information Paper No. 5, p. 1-31. Office of Arid Land Studies, University of Arizona, Tucson.

Yermanos, D.M. 1974. Agronomic survey of jojoba in California. *Econ. Bot.* **28**: 161-174.

Yermanos, D.M. 1977. Jojoba - genetically controlled botanical traits. *Jour. Amer. Oil Chem. Soc.* **54**: 545-548.