Some promising under utilized industrial crops for cultivation on wastelands of India

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Abstract

With ever increasing population and fast depletion of natural resources, it became necessary to explore the possibilities of using newer plant resources. New crops and new usages of old ones hold promise to restore the balance of trade, reduce our dependence on imports and to meet the growing needs of food, clothes and industrial products for human population. This paper provides a brief overview of such under utilized and potential industrial crops, viz. guayule (for rubber), jojoba, Jatropha, tumba and Paradise tree (for edible oil). This account includes data mainly based on field experience, markets surveys, ethno-botanical information and available relevant literature. The results of recent efforts on under utilized plants in the industrial crop group, made under the All India Coordinated Research Project (AICRP) on Under Utilized Plants (UUP) at NBPGR, New Delhi, towards collection, evaluation, utilization and conservation/maintenance have also been highlighted.

Keywords : Industrial Crops, Under utilized plants, Wastelands, Jatropha, Tumba, Guayule, Paradise Tree.

IPC code; Int. cl.7 — A01G 7/00, C11B 1/04, C08L 7/00

Introduction

Agriculture in today’s context is one of the important sources of renewable wealth in the world. It is estimated that so far man has used about 3000 plant species for food and other purposes all over the world (Zeven & Zhukovsky, 1975). There are many plants still lying unexplored and underexploited. Therefore, there has been focussed attention by the researchers on exploiting alternative plant species or under utilized industrial species for multifarious uses. Under utilized industrial crops constitute the lesser-known species in terms of trade and research, often well adapted to marginal and stress conditions. Generally they possess promising industrial importance for a variety of purposes for humankind. Their commercial importance and market value is unknown to the public. Research on these crops hold promise to attain sustainability, profitability and diversification in agriculture and to restore the balance of...
In order to strengthen further research in this direction, an All India Coordinated Research Project (AICRP) on Under Utilized Plants (UUP) was initiated in 1982 with its headquarters at National Bureau of Plant Genetic Resources (NBPR), New Delhi, with 15 main centers and 10 cooperating centers in different agro-climatic zones of the country. The project embraces research work on food, fodder, hydrocarbon and industrial plants. A number of industrial crops, viz. *Parthenium argentatum* Gray (Guayule) for rubber, *Simmondsia chinensis* (Link.) Schneider (Jojoba), *Jatropha curcas* Linn., *Citrullus colocynthis* Schrad. (*Tumba*) and *Cuphea* sp. for industrial oil, and *Simarouba glauca* DC. (Paradise tree) for edible oil, have been identified for research under the AICRP on UUP and research have been carried out for adaptability and cultivation of these plants in various parts of India (Paroda, 1979; Bhag Mal, 1988; Bhag Mal & Joshi, 1991; Paroda & Bhag Mal, 1989, 1992; Joshi et al., 2002). Augmentation of germplasm has been done from National and International sources through NBPGR, New Delhi. *Parthenium argentatum* (Guayule), *Simmondsia chinensis* (Jojoba) and *Cuphea* sp. have been introduced from USA, *Simarouba glauca* (Paradise tree) from El Salvador, and *Jatropha curcas* and *Citrullus colocynthis* (*Tumba*) are found growing wild in India. Research work on guayule is being undertaken at Hisar Agricultural University, Haryana; jojoba at NBPR Regional Station, Jodhpur, Rajasthan and Central Salt and Marine Chemicals Research Institute (CSMCR), Bhavnagar, Gujarat; *Cuphea* sp. at NBPR Regional Station, Shimla; *Tumba* at IARI Regional Station, Mandore, Rajasthan; *Jatropha* sp. at Gujarat Agricultural University, Sardarkrushinagar, Gujarat and Paradise tree at Tamil Nadu Agricultural University, Mettupalayam, Tamil Nadu and by State Government of Orissa. The germplasm assembled, evaluated and maintained in the industrial crops have been listed out in Table-1.

**Research efforts on under utilized species of industrial crop group**

Recognizing the potential of new plant species for use as food, fodder, energy and industrial crops, work on collection, introduction, domestication and utilization was initiated in 1960’s at the Indian Agricultural Research Institute, New Delhi. This activity was later extended to other research centers in the country.}

**Under utilized industrial species**

Plant species have not been exploited equally from different phyto-geographical regions of the world for their uses as industrial crops. Majority of these species have been collected by researchers from wild or semi-cultivated state. They
are in use/cultivation in localized areas only. In India, two of these species (*Jatropha curcas* and *Citrullus colocynthis*) are gathered by local people from wild and exploited for commercial use as industrial oil. *Simmondsia chinensis*, *Jatropha curcas*, *Citrullus colocynthis*, *Cuphea* are utilized for industrial oil, *Simarouba glauca* for edible oil and *Parthenium argentatum* for rubber. These exotic industrial crops have now been acclimatized to Indian conditions and are grown in different states of India, viz. jojoba in states of Rajasthan and Gujarat, Paradise tree in Tamil Nadu and Orissa. Their history, origin and distribution, botany, utilization and cultivation aspects have been discussed in details in this paper.

**Guayule (*Parthenium argentatum* Gray)**

Guayule provides an alternate substitute to rubber tree, which can be grown suitably in wastelands and marginal areas of semi-arid regions. Guayule belongs to family *Asteraceae*. Of the 16 species of the genus *Parthenium*, this is the only species known to produce rubber and it can be used as a commercial source of natural rubber. At present, *Hevea* sp. tree provides the natural rubber used all over the world. Cultivation of this tree is restricted to a limited tropical zone, mainly in South-east Asia. Hence, biological change in this small zone could endanger world’s supply of natural rubber from *Hevea*.

Guayule plant is a native of Chihuahuan desert of North-Central Mexico and South-Western United States (Hammond & Polhamus, 1965). In 1942, the Emergency Rubber Project was initiated in USA to domesticate and develop guayule as an alternative rubber crop during World War II. Guayule grows in a wide variety of shallow, stony, calcareous and friable soils. Annual rainfall in its native habitat is 230 to 400 mm but water requirements have been reported to be 450-600 mm (Anonymous, 1977). Excessive irrigation (1330 mm) in arid regions has been reported to cause faster growth, higher rubber yield and early harvesting (Bucks *et al.*, 1985).

It is a woody perennial shrub less than 135cm in height and produce silver grey leaves. The flowers are produced in

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Table 1: Current status of germplasm build-up in industrial under utilized crops in India

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clusters in inflorescences on peduncles which extend outward in all directions from the plant. The inflorescence forms a spherical cluster containing bisexual flowers.

Agronomic and genetic research was initiated to increase rubber production. At HAU, Hisar ten genotypes were studied for twelve qualitative characters. Analysis of variance showed significant variability and potential for improvement through breeding (Chhabra et al., 1990). Rubber in the guayule plant is located in stem, root and branches in sclerenchyma cells of cortical tissues (Joshi et al., 1994). Plants having longer vascular ray fissures contain more rubber (Mehta, 1979). Large number of leaf hairs have shown positive correlation with rubber content (Healey et al., 1986).

Guayule rubber is similar to Hevea rubber in chemical composition and can be used for manufacture of all the products as those of Hevea. Variation of 8-26 per cent has been observed in rubber content of wild population of guayule at USA. Chemical analysis of available germplasm in India revealed that rubber content varied from 3.4-7.00 per cent while the resin content varied from 4.69 - 6.25 per cent (Chhabra et al., 1990).

**Cultivation practices**

Studies conducted at monthly intervals at Delhi indicated that the best time for raising the nursery under North-West Indian conditions is February (Bhag Mal et al., 1994). Agronomic studies (Joshi et al., 1994) showed 60 cm to be the optimum spacing between rows and 45 cm between plants. Fertilizer application of 40 kg N and 30 kg P for first year and 20 kg N in second year is congenial for good growth of guayule. Irrigation during March-June induce good growth.

**Jojoba [Simmondsia chinensis (Link.) Schneider]**

Jojoba is a desert shrub belonging to the family Simmondsiaceae. This plant can survive on rocks, gravel and sand but is unable to withstand marshy land environments. It can withstand drought, tolerate salinity and wide range of temperatures, rainfall and desert habitat conditions (Anonymous, 1975). Due to slow growth in its wild habitat, it was unknown to commercial cultivators earlier. In 1970's Jojoba's industrial and agronomic importance attracted public attention when it became known that its beans contain about 45-55% liquid wax with chemical properties similar to those of the body fat obtained from sperm whales. It was introduced in India due to its high economic potential mainly as a substitute to sperm whale oil.

Jojoba (pronounced as hohoba) is a native to the Sonoran deserts of North-West Mexico and to the adjoining areas of Arizona and Southern California. 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 (Anonymous, 1975). Other countries with similar climates are already in the process of introduction and many countries including India have taken up its cultivation. Jojoba was first introduced in Indian arid region in 1965 (Harsh et al., 1987) and later on by NBPGR, New Delhi from United States of America. The research work has been carried out at one of its Regional Stations at Jodhpur (Bhatnagar et al., 1991) and the plant has adapted well and popularized in Rajasthan. Now, jojoba plantations have been established in various areas in Rajasthan (Alwar and Jaipur) for commercial purposes also.

Jojoba is called by many names, viz. Bushnut, Bucknut, Deernut, Pignut, Goat berry, Coffee berry, Wild hazel or Quinine plant. It is an evergreen long living short bush, 1-1.5 m in height with a good canopy. Jojoba is dioecious in nature, bearing male and female flowers on separate plants but, occasionally, hermaphrodite plants are also found. In Indian conditions at Rajasthan (Jodhpur), the flower buds generally appear during December-February and the fruits ripen in April. Occasionally, it has also been observed that the flowers appear in June and the fruits ripen in October. Thus, two flowering and fruiting seasons have been reported. The fruits are about the size of acorns.

Its oil has been used to treat sores, cure stomach problems and restore hair by native North American Indian tribes (Bhatnagar et al., 1991). They also reported food value of the seeds (raw or roasted) which were ground with water and sugar to make various beverages, like a coffee substitute.

The jojoba oil is unlike other vegetable oils, being devoid of glycerides or glycerol and composed of fatty acids connected directly to fully alcohols. It is made up almost exclusively of liquid wax-esters, and thus the jojoba seed oil
is unique in the plant kingdom (Wisniak, 1987). The jojoba oil is a light golden coloured fluid with complete absence of resins, tars or alkaloids and contain only steroids, tocopherols and hydrocarbons. Besides its similarity to sperm whale oil, it has an added advantages 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 and 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. It has a wide potential in the pharmaceutical as well as cosmetic industry in manufacture of various hair-shampoos and creams. Jojoba oil’s current use is in cosmetic and personal care industry due to its unique ability to lubricate without the sense of greasiness. Sulfurized and halogenated jojoba oil can be used for high pressure applications such as in automobile transmissions.

Jojoba seed contains 15% protein (NX 6.25) and about 11% antinutritional compounds such as simmondsin, simmondisin 2’-ferulate, 5-desmethyl simmondisin and didesmethyl simmondisin (Kleiman, 1990; Wisniak, 1987).

Cultivation practices

Jojoba can be grown on any type of soil including gravel and rocky soil, except heavy soil and soil prone to flooding. Its pH requirement ranges from 5 to 8 indicating its tolerance to acidity as well as alkalinity. It can tolerate extreme temperatures ranging from 5 to 54°C.

J. curcas is domesticated in the tropical and sub-tropical parts of the world chiefly in Africa and America. The plant is reported to have been introduced in Asia by the Portuguese as an oil yielding plant. It is cultivated to a certain extent as an oilseed crop in Cape Verde Island. J. curcas is a large shrub, 3-4 m high, leaves alternate, 10-15 cm × 7.5-12.5 cm, broadly ovate, cordate, acute, usually palmately 3 or 5 lobed, glabrous; flowers in loose panicles of cymes, yellowish green, fruits 2.5 cm long, ovoid, black, breaking into three 2-valved cocci; seeds ovoid-oblong dull, brownish black. It flowers in hot and rainy seasons, and set fruit in winter when it is leafless. This plant once established, gives economic yield for next 15-20 years under cutting management. This plant has potential to give seed yield as higher as 7-8 tonnes/ha/year after five years of growth. Its well developed tap root which penetrates to several meters has substantial laterals. The well developed secondary root system is much branched and often deeply penetrating to take maximum advantage of soil moisture, a major factor in the plants resistant to droughts. This plant is
well adapted in the semi-arid conditions of Rajasthan and other parts of the country on marginal lands.

It is cultivated mainly as non-edible oilseed crop. The seed of *J. curcas* contains about 38–40% non-edible oil regarded as a potential fuel substitute of diesel. This oil is more viscous than diesel and has low ignition quality. Seed oil is used for manufacturing candles, soap, as lubricant and for illumination; also used as purgative. Besides these uses, oil is also used in cosmetic and wool industry. Bark yields a dark blue dye used for dyeing cloth and fishing nets. Latex of the plant dries to bright reddish brown for use as a purgative. Besides these uses, latex is also used as a purgative. Seed oil is used for manufacturing candles, soap, as lubricant and for illumination; also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative. Seed oil is also used as purgative.

There is great possibility to exploit its oil’s inbuilt potential to produce bio-diesel from seeds so that its use as a diesel can curtail the import of liquid fuel vis-à-vis and save the foreign exchange that in turn can help in sustainable rural development. At Tamil Nadu Agriculture University, Coimbatore an agricultural research technologist specializing in biofuels and rural livelihood security has been working on it for the past several years. He has perfected the technology for extracting the seed oil, refining it and tested it extensively in diesel engines in various combinations as well (Gambhir, 2003). The seeds contain about 28 to 35 per cent by weight a viscous oil that can be used as an extender or trans-esterified to biodiesel. Cultivation of this species generates an income of Rs. 25000 per hectare in a year and if grown over 200 hectares it can provide adequate employment to all landless workers all through the year.

**Cultivation practices**

*J. curcas* can be easily propagated through direct seeding or cuttings. It is desirable to raise seedlings in poly bags and later transplant them in the field during rainy season to avoid any mortality in the field. The land should be ploughed once or twice depending on the nature of the soil. The seeds are to be dibbled at each spot at desired spacing and when the seedlings are four weeks old; weaker seedlings should be removed. Eight to ten week old seedlings are to be planted in 30 cm × 30 cm pits dug in the field at required spacings and filled with a mixture of soil, FYM (2-3 kg) and fertilizer (20 gm Urea, 120 g single super phosphate and 16 g Murate of potash). The NPK in the ratio of 46:48:24 kg/ha is to be applied in split doses from second year onwards so as to obtain higher yields. Under irrigated or partially irrigated conditions, a distance of 2 m between row-to-row and plant-to-plant may be maintained. But under rainfed conditions on wastelands, high density plantation at 2 m × 1 m or 1.5 m × 1.5 m row-to-row and plant-to-plant distance can be raised. For these spacings approximately 4-5 kg seed/ha will be required for sowing. Interculturing should be carried out as and when required. Annually 3-4 weedings may be carried out for keeping weed free field during initial growth period. During dry period only life saving irrigations should be applied to the plants. Usually from second year onwards irrigation is not required unless soils are shallow and sandy.

The plant starts bearing fruits from second year onwards. However, an estimated seed yield of approx. 2000 to 3000 kg/ha/year and 5000 kg/ha/year can be expected from rainfed and irrigated plantations, respectively, from six year onwards. The cultivation of *J. curcas* could generate employment to the extent of approximately 35,000 man days.

**Paradise tree (Simarouba glauca DC.)**

Paradise tree also known as Aceituno, belongs to family Simaroubaceae. This species, commonly called as King of oilseed trees, is an evergreen tree and is native of El Salvador, Brazil. It is suitable to various weather conditions and is particularly a drought tolerant species. It is a dioecious species with a male to female ratio of 3:2.

The tree was introduced in India in 1966 from El Salvador by the then Plant Introduction Division (Now National Bureau of Plant Genetic Resources) of IARI, New Delhi. This plant has wide adaptability and thrives well in semi-arid climatic conditions. From NBPG Regional Station, Akola (Satellite Centre, Amravati) the plant has spread to many states like Orissa, Tamil Nadu, Andhra Pradesh and Karnataka, where its cultivation has been done successfully in forest and other wastelands.

It is an evergreen, dioecious, medium sized tree, attaining a height of 15 - 20 m with a large circular crown. The bark is smooth and grey in colour. The leaves are opposite, pinnately compound, oblong, acuminate, dark oily green on dorsal side and pale green on ventral side. Inflorescence is raceme with white/light yellow flowers. Fruit is a drupe, 1-seeded, medium sized, ovate, with hard shell (Patel et al, 1997).
Kernels of paradise tree, which form 92% of the seeds, on decorticitation yield 55 - 60% oil suitable for human consumption without hydrogenation or blending with other fats. The snow white refined fat is passed over a chill-roll before packing. Its melting point is 28°C. The chemical composition of seeds and shell is 61.82% and 2.80% oil, 0.31% and 0.58% amino acids, respectively. On account of its shining dark green leaves, paradise tree can also be grown for avenue plantation (Phogat & Sharma, 2000).

Cultivation practices

Seeds of *S. glauca* are sown in polythene bags or in nursery bed during March-April and are ready for transplanting by middle of August. Alternately, seeds can be dibbled directly in pits @ 2 seeds/ hill. The seedlings are ready for transplanting in about three months. For transplanting/direct seeding, pits of 60 cm × 60 cm × 60 cm size are dug at a spacing of 6 m × 6 m. The soil is mixed with farmyard manure in equal measure and filled in the pits. Two plants/ seeds are planted per pit. After establishment one of the seedlings can be uprooted. Regular watering and weeding are needed for proper establishment of seedlings. Since this plant is dioecious in nature, a sufficient number of male plants (1 male: 10 females) are needed to ensure proper fruiting of female plants. After initial establishment, this plant grows fast and attains a height of 3 - 5 m in 3 - 4 years. It starts flowering after the fourth year of planting. Initially, the flowers are borne on few twigs, resulting in less fruit yield of 10 - 12 kg/tree (115 qt/ha from 150 female trees). However, a yield of 40-50 kg/tree is possible from a well-grown tree of 12-15 years. Oil yield of 8-9 qt/ha can be achieved after 7-8 years of planting. The plants should be protected from termites and stem borer by adopting suitable plant protection measures. Fruits of paradise tree drop on the ground on attaining maturity and have to be simply collected for harvest.

**Colocynth (Citrus colocynthis Schrad.)**

Colocynth (*Tumba*) is a multipurpose crop belonging to family *Cucurbitaceae*. It is a perennial creeper spreading in the field on all sides. This is known by different names in different states of India, viz. *Ghudmba* in Punjab, *Indark* in Gujarat, *Makal* in Bengal and *Kartama* in South India. The extensive growth of its branches to greater lengths, in sandy undulated plains and sand dunes play an important role in controlling soil erosion in desert areas.

*Tumba* is a native of the warmer parts of Asia and Africa. It occurs throughout India and is seen growing wild in the warm arid and sandy tracts of North-West, Central and South India and on the sea shores of the coromandal coast, Gujarat, and other parts of western India. It is found in wild form in desert area of Rajasthan, namely Bikaner, Barmer and Jaisalmer and is found growing wild in the districts of Jodhpur, Nagaur, Churu and Sikkar (Paroda, 1979; Whth India, 1992).

It is an annual or perennial herb with a prostrate or climbing stem, bearing smooth spherical fruits which are mottled green when young and some what yellow when ripe. The fruits are of the size of a small orange, 3-4 inches in diameter and contain a soft spongy pulp and numerous ovate compressed, white or brownish seeds. Multi-locational germplasm evaluation trials have been undertaken in various parts of Rajasthan and promising accessions have been identified. Lot of research work has been carried out and ‘GP-3’ (high yielding perennial cultivar) has been identified at Agriculture Research Station, Mandore, Rajasthan. It spreads up to 4-5 m, on all sides/allover. Its average seed production is 450-600 kg/ ha and oil content is 25-27%. Germination in *tumba* seed is difficult because of its hard seed coat.

The seeds are utilized for industrial oil applications. The dried pulp of the unripe but full-grown fruit, freed from the rind, constitute the drug, colocynth, of commerce. *C. colocynthis* has active ingredient, cissampeline (myorelaxant) in its fruits. The seeds contain 30-34% pale oil which is the main source of profit to farmers. Oil contains an alkaloid, a glucoside and a saponin. The roots have purgative properties and are used in jaundice, rheumatism and urinary diseases (Bhag Mal *et al*, 1995). Oil cake and fruits are main sources of nutrition for feeding the goats in desert areas.

Cultivation practices

*Tumba* is sown at the onset of monsoon season after the first rain shower. Seeds are sown directly in the field in pits of 30 cm × 30 cm and at row spacing of 3 m and plant-to-plant spacing of 1 m.
Two seeds are sown per pit. After establishment, one of the seedlings can be uprooted. Regular watering and weeding is required at the initial growth stages of crop establishment.

**Future thrust**

Specific strategies and dynamic approach is required for sustainable management of new industrial plants. Work on utilization, conservation and sustainable use of such underutilized species should be emphasized upon. Priorities on future collection/exploration trips based on gaps in areas and diversity is required. Basic studies should be done on species to be introduced and conserved.

Some special incentives and subsidies from government should be given to the farmers as well as industrialists to encourage cultivation and commercialization of such crops.

The benefits that would accrue as a result of agricultural diversification and new industrial product development and availability would be significant to both producers and consumers. These factors support strongly for high level research and development that is broadly supported by industry, state and federal sectors. The ultimate success of a new product, of course, depends on generating strong consumer demand. Research and development are just one step in the process of introducing new products to the market place. An equally important step is developing an appropriate marketing strategy that moves a new product from the laboratory to commercial success.

**Conclusion**

Most of the plants discussed in this paper being desert shrub and semi-xerophytic in nature can be cultivated in the available degraded lands of villages as well as in adjoining forests, they have become non-productive. Hence, their large-scale cultivation will lead to sustainable development of wastelands and generate employment for landless poor farmers.

Research is needed to improve seed production with the help of suitable agronomic practices and development of oil processing technology. Research is also required to provide the specific planting material, quality seeds, drip irrigation and well developed technology for extraction, refining and detoxification of oil and agronomic recommendation of appropriate intercropping systems to provide profit to farmers during lean season. Then, only farmers will get attracted and income of average marginal farmers can be protected.

Therefore, these industrial plants have great potential to become important source of industrial oil and other products. Since abundant areas in India are lying uncultivated in arid and semi-arid marginal lands, these plants hold a great promise of providing new industrial raw materials for commercialization.

**Acknowledgements**

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**References**

7. Bhag Mal, Joshi Vandana, Phogat BS and Rathi RS, Guayule (Parthenium argentatum): A lesser known potential source of natural
rubber, *Indian For*, 1994, **120** (6), 519-523.


