

Potentials and *Jatropha* species wealth of India

Abundance and availability of energy resources largely determine the economic wellbeing of a country. Energy independence has to be our first and foremost priority¹. Volatile price and import dependency of petroleum products urged the researchers to explore possible alternate energy sources. In this context, research on energy from nuclear, wind, tidal and biological origins gained great momentum but it needs special infrastructure facilities, whereas biofuels can be produced from a diverse set of crops. Each country is adopting a strategy that exploits the comparative advantages it holds in certain crops. In India, more than 100 species of forest plants – tree borne oil seeds (TBOs) have been identified as a source of fatty oils with an estimated potential of 11.3 lakh tonnes². Plant species which can be processed to provide diesel fuel substitutes have captured the interest of scientists. In this category, the properties of the tropical physic nut (*Jatropha curcas*) have won over the interest of various development agencies and the Planning Commission of India. Limited, scattered and not readily accessible (i.e. only found in ‘grey literature’ or written in specific floras) information on many important and underutilized crops hinders development and their sustainable utilization. *Jatropha* is one such genera about which very little is known and research to meet our future energy requirements is eagerly awaited.

Any crop improvement programme will be successful only after assessing our native genetic strength and the possible options towards yield improvement. In India, a decade ago few native *Jatropha* species were utilized in the castor improvement programme and interspecific hybridization has been attempted between different species of *Jatropha* with limited success^{3,4}. An intensive hybridization programme has been attempted between *Jatropha curcas* and eight other *Jatropha* species⁵ to develop new hybrids with higher yield potential and resistance to diseases. The cultivated species *J. curcas* was used as the female parent and the species, viz. *J. integririma*, *J. podagrica*, *J. villosa*, *J. tanzanensis*, *J. gossypifolia*, *J. glandulifera*, *J. multifida*, *J. maheswari* and *J. villosa* were used as pollen donors. Hybridization between *J. curcas* and *J. integririma*

produced successful hybrids with more seed set, whereas the other crosses failed to produce seeds due to existence of crossability barriers either in pre-zygotic state or in post-zygotic state. In the successful hybrid also, the F₁ progeny has exhibited vigorous growth, but the fruit was small in size resembling *J. integririma* characters. Hence, a backcross was attempted to get progeny with unique fruit, seed and oil yield characteristics. Way back in 1910, Pax⁶ reported the occurrence of *Jatropha* natural hybrids in some South American species; *J. cinerea*–*J. canescens* complex in Mexico⁷ and a hybrid complex of *J. integririma*–*J. hastata* in Cuba³. Although every *J. curcas* is well known, the unanswered question before us is the wealth of *Jatropha* species in India. An extensive survey of the literature (journals, books, internet, etc.) and the Indian soil from Jammu to Kanyakumari made possible a collection of *Jatropha* species available in India (Figure 1) along with the botanical description following Michael Simpson’s⁸ plant systematics. This information will pave the way for possible options towards *Jatropha* yield improvement through interspecific hybridization⁹, interspecific grafting¹⁰ and molecular transformation of traits of interest from one species to another.

In general, the genus *Jatropha* belongs to the tribe Joannesieae of Crotonoideae in the Euphorbiaceae family and contains approximately 170 known species distributed in the tropical and subtropical Africa and America. Most of the *Jatropha* species are native to new world and no complete review of the 66 old world *Jatropha* exists¹¹. Plants of this genus are herbs, shrubs or trees, monoecious (rarely dioecious), exudates is watery to white; possess poisonous substance in the sap/seed. Indumentum has simple hairs and sometimes glandular hairs; leaves alternate, often digitately lobed. Flowers are terminal cymes with a single pistillate flower at the end of the primary axis. Sepals are 5 in number, free, imbricate; petals – 5, mainly free; staminate disc annular or 5 free glands, stamens 6–10, in two whorls; pistillate foliaceous annular, 5-lobed; fruits capsular to tardily dehiscent and sub-drupaceous¹².

Even though 12 *Jatropha* species were notified by several Indian floras, research

has been confined to nine species only. Among the *Jatropha* species, *J. curcas* is the most primitive form and has the potential to be cultivated for biodiesel and medicinal properties. The following are the *Jatropha* species available in India and its description for identification.

1. *Jatropha curcas* L. – First named by Linnaeus (1753) and the word is derived from Greek ‘Jatros’ (doctor) and ‘trophe’ (food/nutrition) which implies medicinal uses. A large shrub grows up to 3–4 m high, native to tropical America and introduced to Asia and Africa by the Portuguese in the 16th century¹². Adapted to grow in all parts of India except frost prone area. The plant is a diploid with $2n = 22$ chromosomes. Leaves are 3–5 lobed, cordiform, stipules deciduous. Inflorescence is complex, monoecious with protandry. First branching is racemose and subsequent branches are cymes. Inflorescence is a cyathium which appears as a single flower. Each cyathium is surrounded by an involucre of five connate bracts and between these, large glands are present which bear a petaloid appendage. Cymes are up to 12 cm in length, flowers greenish white and unisexual. In the middle of the cyathium, there is a single female flower with tricarpellary gynoecium. In the axil of each bract are present a number of male flowers with a single stamen and joined half way up to the stalk in scorpioid cymes. The oldest flower is nearest to the centre and thus the maturation is centrifugal. Normally the male to female ratio varies from 16/27:1 to 108:1. Generally flowers between September and January and second flowering in June is also reported. The inflorescence, once it begins flowering, flowers daily, and the flowering lasts for 11 days. Cross pollinating by insects encouraged by hermaphrodite¹³. Staminate, slightly fused petal-based, stamens 5 + 5, 5 outer filaments only basally united, inner 5 completely united; pistillate petals are free or basally slightly united. Fruits ellipsoid, mostly trilobed, hardly tetralobed, dehiscent loculicidally; seeds compressed ovoid–ellipsoid by 1 cm, caruncle minute and weights about 0.417 to 0.575 g. Propagated by seeds or by cuttings. This 50 years of rotation species can yield 2–4 tonnes of seed/ha with 30–42% of oil content after three years of planting¹⁴.

2. *Jatropha gossypifolia* L. – Perennial ornamental shrub up to 3 m tall, native to Brazil. The palmately opposite leaves are 3–5 lobed, deciduous in winter. Stipules are ciliate, glandular margin of leaves, petiole and leaf blade covered with glandular hairs. Flowers unisexual, monoecious, purple red with yellow centres and produced in clusters on branched stalk in the upper leaf axils. Male to female ratio is 11:1. Stamens 5 + 3, filaments basally connate, inner 3 longer. Fruit is a capsule, 3 lobed, 1.7×1.5 cm

size, dehiscent, seeds oblong. It is intolerant to shade with an yield potential of 500 kg/ha of seeds, seed shell to kernel ratio by dry weight is 35:65, and the seed oil content is 28–30%¹⁴. Young leaves are purple in the variety *elegans* whereas all the parts will be green in variety *gossypifolia*. The variety *gossypifolia* possesses less hairs in the fruit and the fruit size will be larger¹⁵. Both the varieties are common in waste/disturbed lands from coastal up to 500 m elevation. Propagation is by cuttings and by seed.

3. *Jatropha glandulifera* Roxb./*J. glauca* Vahl. – An evergreen shrub about 2 m in height, distribution confined to the black cotton soils of the Deccan and Carnatic. It is known as ‘Adalai’ in Tamil and distributed in Chengalpattu, Coimbatore, Dharmapuri, Pudukkottai, Ramanathapuram, South Arcot, Trichy and Tirunelveli districts of Tamil Nadu. This species contains clear pale yellow juice, purplish tender parts, short and stout trunk and has smooth papery bark. Leaves are palmate, 3–5 lobed, margin serrate, serratures and stipules gland-tipped. Flowers greenish yellow, unisexual, in glandular corymbose cymes; bracts long, lanceolate, acute, with gland tipped hairs on the margins. Male flowers: calyx 1/8 inch long, divided almost at the base; segments ovate, obtuse. Stamens 8, diadelphous, 5 + 3, inner longer, capsule 3 lobed, seeds ellipsoid, 1/3 inch long, smooth, shining, black coloured with 20–27% of brownish yellow oil. Flowering and fruiting is through the year and is propagated by seeds and cuttings¹⁶.

4. *Jatropha multifida* L. – A glabrous shrub, native to South America. Cultivated in gardens, parks for ornamental foliage and flowers and known as coral plant. It is known as ‘malai amanakku’ in Tamil. Leaves 20–35 cm length across, 5–11 lobes oblanceolate, again lobed at apex, glaucous beneath, acuminate base obtuse or cordate, petioles up to 20 cm long, green above, often pale pink below and turns to green at maturity. Inflorescence tightly corymbiform, up to 28 cm long, flowers deep red, in axillary long peduncled cymes, unisexual, monoecious. Stamens 8–10 filaments, shortly connate. Capsule obovoid, smooth, yellowish, trilobed, lobes slightly keeled. Seeds obovoid, brown in colour contain 32–40% of oil¹². Flowering and fruiting appear mainly during the rainy season and it is mainly propagated by seeds.

5. *Jatropha tanjorensis* Ellis and Saroja – It is a natural hybrid between *J. curcas* and *J. gossypifolia* mainly confined to Mettur dam and Tanjore region of Tamil Nadu¹⁷. It is vigorous in growth but sterile in nature, growing up to 3 m, tender parts brownish in colour. Leaves palmately five folded, margins distinctly serrate, long petiole with dense pigmentation. Flowers pinkish green, unisexual/bisexual but monoecious, polygamous. Stamens 8, free, pollen sterile. Fruit does not set and is propagated by cuttings¹⁸.



Figure 1. Available *Jatropha* species in India.

6. *Jatropha podagrica* Hook. – Small shrub, up to 1 m height, native of Panama. Often found in conservatories, gardens and parks but thrive well in rich soil fully exposed to the sun and regularly watered. ‘Podagrica’ is a Latin word meaning ‘gouty’ and refers to the swollen base of the plant. Branches are soft and succulent, deeply scarred where the leaves have fallen away, 25–30 cm length leaves, peltate, long petiolated, glabrous, glaucous 3–5 lobed, lobe subovate with margins devoid of serration, orange red or scarlet flowers on terminal, long stalked cymes, unisexual, monoecious, male flowers are more in number than female flowers. Stamens 6–8, seated in a yellow disk, furnished with 5 yellow glands, filaments red. Fruits: 3 cm long, initially green turning brownish on maturity and dehiscent. The seed shell to kernel ratio by dry weight is 25:75. Seed yield is 400 kg/ha with oil content up to 54%¹⁴. Flowering and fruiting through the year and propagated by division or seed.

7. *Jatropha integerrima* Jacq. – An erect ornamental shrub, native to West Indies, grows up to 6 m tall, sparingly pubescent. Stipules filiform, petiole 1–3 cm long, glabrous, base attenuate, margin entire except usually subbasally glandular–denticulate, apex acuminate to cuspidate, tip acute, venation basally 3–5 nerved, with up to 12 pairs nerves along the midrib. Inflorescence terminal, peduncle up to 10 cm long, bracts triangular, basally with glandular teeth. Scarlet or pinkish unisexual flower, monoecious. Stamens 10, the 5 outer filaments united for three quarters, the inner ones united for two-thirds of their length¹⁹. Fruits trigonous, 1 cm in diameter, dehiscent. Seeds are small, slender, ellipsoid to ovoid. Propagated by cuttings.

8. *Jatropha pandurifolia* Andr./*J. hastata* Jacq. – Shrubs, up to 3 m tall, with slender, graceful branches, native to Cuba. ‘Pandurifolia’ in Latin means ‘with fiddle shaped leaves’. Leaves alternate, shallowly cordate at the base, where there are 3–4 glandular teeth on each side. Inflorescence terminal cyme, dioecious, calyx purplish red in colour. Petals twisted in the bud, white hairs inside at the base. Stamens 8, often 4 long, 4 short. Filaments joined in a column and red. Fruit is a capsule, purplish green in colour²⁰. Flowering through the year and propagated by cuttings or by seed²¹.

9. *Jatropha villosa*/J. *peltata* Wight./*J. wightiana* Wight. and Muell. – Under-

shrub, shoots rusty – villous. Indigenous to India, known as ‘thanakku’ in Tamil. Leaves 4–6 inch in diameter, tomentose beneath, shallowly 3–5 lobes, 5 nerved. Cymes corymbose, peduncle stout, flowers pale yellow. Calyx lobes are lanceolate and corolla salver shaped. Stamens 8, basally connate, capsule 3 cm long²². Variety villosa confined to Coimbatore, Dharmapuri, Salem and Nilgiris of Tamil Nadu whereas variety ramanadensis distributed only in Ramanathapuram in Tamil Nadu.

10. *Jatropha nana* Dalz. – A small, sparingly branched shrub, 30–45 cm high, found in stony and waste places near Poona and Mumbai, being apparently endemic to the Deccan, dwarf of African type²³. Root woody as thick as finger, stem round, smooth. Leaves 3 lobed/entire, 7.5–12.5 cm long and about equally broad with the largest middle lobe. Base euneate, with three strong nerves from the base, petiole variable in length. Stipules not seen. Flowers pedicellate, in few flowered terminal paniculate cymes. Stamens 8, all united in the lower half. Flowering occurs from May to July. Fruits: capsule, 1 cm long, obovoid–oblong, flattened at the top, slightly 6 lobed¹².

11. *Jatropha heynei* Balakr./*J. heterophylla* Hook. – A small (15–30 cm tall), low glabrous shrub, branching (up to 6) from a tuberous rootstock (weighs about 1 kg). Distribution confined to the Indian peninsula²². Leaves deeply 3-fid, 3 nerved, lobes oblanceolate. Flowers unisexual, very small. Flowers and fruits green in colour. Stamens 8–10, filaments shortly connate. Flowering and fruiting seasons from August to September and the fruit is a capsule²⁴.

12. *Jatropha maheswari* Subram. and Nayar. – An evergreen undershrub, narrow, small and lanceolate leaves. It is a fertile, drought hardy and rhizomatous plant having 22 chromosomes. Distributed in the southern districts of Tamil Nadu²⁵.

Table 1 describes the different *Jatropha* species, important morphological characters and the desirable traits available in them. Among the available *Jatropha* species, the physic nut is hoped to feed our future green energy demands. It has already occupied more than 2,50,000 acres in India²⁶. It is a wild growing, hardy plant well adapted to arid and semi-arid conditions and can grow well in low fertile, moisture and even calcareous

soil. Its performance in the winter prone areas is doubtful and needs careful introduction in those regions. In spite of some doubts regarding this species, it holds promise due to the success of intraspecific²⁷ and interspecific hybrids⁵ and their yield potential. It is commercially propagated by seeds and by stem cutting. Fully matured fresh seeds were selected for sowing and pre-soaking in water/cowdung slurry for 12 h is advised to get vigorous seedlings. Soaked seeds are sown in polybag (10 × 20 cm size) filled with soil, sand and FYM (farm yard manure) in the ratio of 1:2:1 respectively. Germination is generally noticed after 4–5 days and continues up to 15 days and seedlings are ready for planting after 4–6 months of maintenance in the nursery. *J. curcas* responds well to vegetative propagation also²⁸. Propagation through branch cuttings is not new and farmers use it as a biofence in their fields. In fact, 90% *Jatropha* was spread throughout the country as ‘live fence’ by branch cuttings only. Cuttings planted during monsoon immediately after the first showers can give better root initiation, higher survival and good growth performance. Eight to ten-week-old seedlings are to be planted in 30 × 30 cm pits dug in the field at required spacing and filled with a mixture of FYM (2–3 kg) and fertilizer (20 g urea, 120 g single super phosphate and 16 g murate of potash). NPK in the ratio 46:48:24 kg per ha is to be applied in split doses from second year onwards so as to obtain economic yields and high oil content in seeds²⁵. Since all other *Jatropha* species were known for their ornamental value, the cultivation practice was not standardized for those species.

Presently *Jatropha* yield improvement is largely attempted either by selection or by cultural/management practices. In India, a biofuel mission was started in 2003 and the Government has announced a biofuel policy in September 2008 with a proposal of 20% blending of biofuels with petrol and diesel by 2017 (ref. 29). Moving towards biofuels for a secure and clean energy future³⁰ will be possible only after understanding of our *Jatropha* wealth and its potential. The information available on *Jatropha* species of India can be used to explore the potential for possible yield improvement strategy through intraspecific, interspecific and intra-generic hybridizations; interspecific grafting, and genetic transformation. Earlier, few *Jatropha* species were collected

Table 1. Important morphological features and desirable traits of different *Jatropha* species

Sl. no.	Species	Native place	Distribution in India	Important morphological features	Oil (%) content	Propagation methods	Desirable traits
1	<i>Jatropha curcas</i>	Tropical America	Got introduced in all the states of India	Large shrub, highly branching, cordate–palmately lobed leaves, greenish-yellow flowers, distinct ceflorescence, tardily dehiscent fruits with black, ecarunculate seeds	30–42	Seed, cutting, grafting, air layering and tissue culture	High seed yield and oil content
2	<i>Jatropha gossypifolia</i>	Brazil	Commonly found in disturbed soils of all states	Fertile large shrub, profuse branching, cordate leaves, glandular plant parts, dark crimson–purple flowers, violently dehiscent capsules with small brown carunculate seeds	28–30	Seed and cuttings	Drought-tolerant and profuse, year round fruiting
3	<i>Jatropha glandulifera</i>	India	Black cotton soils of Deccan and Carnatic	Fertile smaller plant, spread and dichotomously branched, narrow leaves with serrated margin, have smooth papery park, profuse fruiting, but dehisce before maturity	20–27	Seed and cuttings	Profuse fruiting and drought-tolerant
4	<i>Jatropha multifida</i>	South America	Ornamental nurseries in all states	Fertile shrub, uniform branching, leaves divided into 5–11 lobes, long petiole and pedunculate, flat-topped cyme, coral-red flowers and fruits are non-dehiscent capsules	32–40	Seed and by cuttings during spring	Bigger fruit size and resistant to diseases
5	<i>Jatropha tanjorensis</i>	India	Tanjore, Trichy, and Ramnad district of Tamil Nadu	Sterile shrub, profuse branching, cordate–palmately lobed leaves, margins distinctly serrate, greenish-yellow flowers with crimson-red tinge, no fruit-set	Sterile	Cuttings	Robust and drought hardy
6	<i>Jatropha podagrica</i>	Panama	Ornamental nurseries in Southern and Central India	Fertile, caudiciform shrubs, cordate leaves with peltate base, flat-topped corymbose cyme, bright scarlet flowers, fruits dehiscent capsule with big brown ecarunculate seeds	Up to 54	Seed and by division of branches	Bigger fruit, Fusarial wilt resistant
7	<i>Jatropha integerima</i>	West Indies	Ornamental nurseries in south India	Fertile shrub, sparsely branched, ovate fiddle-shaped leaves, crimson-red flowers, dehiscent capsules, seeds small carunculate and brown with spots	No report	Cuttings	Semi-hard wood stem and disease-resistant
8	<i>Jatropha pandurifolia</i>	Cuba	Rare in ornamental nurseries	Dioecious shrub with slender, graceful branches. Leaves alternate, shallowly cordate at the base, inflorescence terminal cyme, calyx purplish red in colour. Petals twisted in the bud, white hairs inside at the base. Flowering throughout the year, fruits are capsule and purplish green	No report	Seed and cuttings	Flowering through the year
9	<i>Jatropha villosa</i>	India	Kongan region, Nilgiri, Kanyakumari, and Ramnad districts of Tamil Nadu	Fertile undershrub, shoots rusty – villow, profuse branching, drought-tolerant, evergreen, rhizomatous plant	No report	No report	Evergreen and rhizomatous plant
10	<i>Jatropha nana</i>	India	Poona and Mumbai. Endemic to the Deccan	Shrub with woody root as thick as finger, stem round, smooth. Leaves 3 lobed/entire with the largest middle lobe. Flowers pedicellate, and few flowered terminal panicle cymes. Capsule fruit	No report	Seed	Woody root system
11	<i>Jatropha heynei</i>	India	Indian Peninsula	Shrub, branching from a tuberous rootstock (weighs about 1 kg). Leaves deeply 3-fid, lobes oblanceolate. Flowers unisexual and small. Both flowers and fruit capsules are green in colour	No report	Seed	Tuberous root stock
12	<i>Jatropha maheswari</i>	India	Naturally occurs in southern districts of Tamil Nadu	Fertile evergreen, drought-hardy and rhizomatous plant, leaves long, elliptical and resembles mango leaves	No report	No report	Drought-hardy and rhizomatous plant

and used for the castor improvement programme¹⁷. And a decade ago, the non-toxic *Jatropha* from Mexico was obtained and the *in vitro* propagation method was standardized for its multiplication³¹. Even though Indian search/research on *Jatropha* has been more than a century old, co-coordinated research is needed to attain improved yield.

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