Abundance and availability of energy resources largely determine the economic wellbeing of a country. Energy independence has to be our first and foremost priority. 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 tonnes. 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. An intensive hybridization programme has been attempted between Jatropha curcas and eight other Jatropha species 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. integerima, J. podagrica, J. villosa, J. tanjorensis, J. gossypifolia, J. glandulifera, J. multiloba, J. maheswari and J. villosa were used as pollen donors. Hybridization between J. curcas and J. integerima 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. integerima characters. Hence, a backcross was attempted to get progeny with unique fruit, seed and oil yield characteristics. Way back in 1910, Pax reported the occurrence of Jatropha natural hybrids in some South American species; J. cineerea-J. canescens complex in Mexico and a hybrid complex of J. integerima–J. hastata in Cuba. 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’s plant systematics. This information will pave the way for possible options towards Jatropha yield improvement through interspecific hybridization, interspecific grafting 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 exists. Plants of this genus are herbs, shrubs or trees, monocious (rarely dioecious), exudates is watery to white; possess poisonous substance in 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 follicaceous annular, 5-lobed; fruits capsular to tardily dehiscent and sub-drupaceous.

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 century. 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, monocious 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 scorpion 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 hermaphrodite. Staminate, slightly fleshy 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, dehiscing loculecally; 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 planting.
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 a 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%.

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 park. 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 ellipsoidal, 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 cuttings.

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 corymbose form, 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 oil. 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 Nadu. 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 cuttings.

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**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, glauccus 3–5 lobed, lobe subovate with margins devoid of serration, orange red or scarlet flowers on terminal, long stalked cymes, unisexual, monocious, 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, pubescent. 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 lobed 12.

11. *Jatropha heymei* Balakr., *J. hysterophylla* 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 lobed, nerves oblongate. 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 capsule14.

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

<table>
<thead>
<tr>
<th><em>Jatropha</em> species</th>
<th>Important Morphological Characters</th>
<th>Desired Traits</th>
<th>Available in Them</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>J. podagrica</em></td>
<td>Fertile, drought hardy</td>
<td>Arid and semi-arid conditions</td>
<td>Yes</td>
</tr>
<tr>
<td><em>J. integerrima</em></td>
<td>Fertile, hardy</td>
<td>Arid and semi-arid conditions</td>
<td>Yes</td>
</tr>
<tr>
<td><em>J. heymei</em></td>
<td>Fertile, drought hardy</td>
<td>Arid and semi-arid conditions</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Jatropha* species are 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

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Species</th>
<th>Native place</th>
<th>Distribution in India</th>
<th>Important morphological features</th>
<th>Oil (%) content</th>
<th>Propagation methods</th>
<th>Desirable traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Jatropha curcas</em></td>
<td>Tropical America</td>
<td>Got introduced in all the states of India</td>
<td>Large shrub, highly branching, cordate–palmately lobed leaves, greenish-yellow flowers, distinct coloforescence, tardily dehiscent fruits with black, ecarunculate seeds</td>
<td>30–42</td>
<td>Seed, cutting, grafting, air layering and tissue culture</td>
<td>High seed yield and oil content</td>
</tr>
<tr>
<td>2</td>
<td><em>Jatropha gossypifolia</em></td>
<td>Brazil</td>
<td>Commonly found in disturbed soils of all states</td>
<td>Fertile large shrub, profuse branching, cordate leaves, glandular plant parts, dark crimson–purple flowers, violently dehiscent capsules with small brown ecarunculate seeds</td>
<td>28–30</td>
<td>Seed and cuttings</td>
<td>Drought-tolerant and profuse, year round fruiting</td>
</tr>
<tr>
<td>3</td>
<td><em>Jatropha glandulifera</em></td>
<td>India</td>
<td>Black cotton soils of Deccan and Carnatic</td>
<td>Fertile smaller plant, spread and dichotomously branched, narrow leaves with serrated margin, have smooth papery park, profuse fruiting, but dehisce before maturity</td>
<td>20–27</td>
<td>Seed and cuttings</td>
<td>Profuse fruiting and drought-tolerant</td>
</tr>
<tr>
<td>4</td>
<td><em>Jatropha multifida</em></td>
<td>South America</td>
<td>Ornamental nurseries in all states</td>
<td>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</td>
<td>32–40</td>
<td>Seed and by cuttings during spring</td>
<td>Bigger fruit size and resistant to diseases</td>
</tr>
<tr>
<td>5</td>
<td><em>Jatropha tanjorensis</em></td>
<td>India</td>
<td>Tanjore, Trichy, and Ramnad district of Tamil Nadu</td>
<td>Sterile shrub, profuse branching, cordate–palmately lobed leaves, margins distinctly serrate, greenish-yellow flowers with crimson-red tinge, no fruit-set</td>
<td>Sterile Cuttings</td>
<td>Robust and drought hardy</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><em>Jatropha podagrica</em></td>
<td>Panama</td>
<td>Ornamental nurseries in Southern and Central India</td>
<td>Fertile, caudiciform shrubs, cordate leaves with peltate base, flat-topped corymbose cyme, bright scarlet flowers, fruits dehiscent capsule with big brown ecarunculate seeds</td>
<td>Up to 54</td>
<td>Seed and by division of branches</td>
<td>Bigger fruit, Fusarial wilt resistant</td>
</tr>
<tr>
<td>7</td>
<td><em>Jatropha integer-rima</em></td>
<td>West Indies</td>
<td>Ornamental nurseries in south India</td>
<td>Fertile shrub, sparsely branched, ovate fiddle-shaped leaves, crimson-red flowers, dehiscent capsules, seeds small carunculate and brown with spots</td>
<td>No report</td>
<td>Cuttings</td>
<td>Semi-hard wood stem and disease-resistant</td>
</tr>
<tr>
<td>8</td>
<td><em>Jatropha panduriformia</em></td>
<td>Cuba</td>
<td>Rare in ornamental nurseries</td>
<td>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</td>
<td>No report</td>
<td>Seed and cuttings</td>
<td>Flowering through the year</td>
</tr>
<tr>
<td>9</td>
<td><em>Jatropha villosa</em></td>
<td>India</td>
<td>Kongan region, Nilgiri, Kanyakumari, and Ramnad districts of Tamil Nadu</td>
<td>Fertile undershrub, shoots rusty – willow, profuse branching, drought-tolerant, evergreen, rhizomatous plant</td>
<td>No report</td>
<td>No report</td>
<td>Evergreen and rhizomatous plant</td>
</tr>
<tr>
<td>10</td>
<td><em>Jatropha nana</em></td>
<td>India</td>
<td>Poona and Mumbai. Endemic to the Deccan</td>
<td>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 paniclec cymes. Capsule fruit</td>
<td>No report</td>
<td>Seed</td>
<td>Woody root system</td>
</tr>
<tr>
<td>11</td>
<td><em>Jatropha heyniei</em></td>
<td>India</td>
<td>Indian Peninsula</td>
<td>Shrub, branching from a tuberous rootstock (weighs about 1 kg). Leaves deeply 3-fid, lobes ob lanceolate. Flowers unisexual and small. Both flowers and fruit capsules are green in colour</td>
<td>No report</td>
<td>Seed</td>
<td>Tuborous root stock</td>
</tr>
<tr>
<td>12</td>
<td><em>Jatropha maheswari</em></td>
<td>India</td>
<td>Naturally occurs in southern districts of Tamil Nadu</td>
<td>Fertile evergreen, drought-hardy and rhizomatous plant, leaves long, elliptical and resembles mango leaves</td>
<td>No report</td>
<td>No report</td>
<td>Drought-hardy and rhizomatous plant</td>
</tr>
</tbody>
</table>
and used for the castor improvement programme\(^1\). And a decade ago, the non-toxic \textit{Jatropha} from Mexico was obtained and \textit{in vitro} propagation method was standardized for its multiplication\(^3\). Even though Indian search/research on \textit{Jatropha} has been more than a century old, co-coordinated research is needed to attain improved yield.

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\end{enumerate}

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