Chemobotany of *Jatropha* species in India and further characterisation of 'curcas oil'

ASHOK K. RAINA and B. R. GAIKWAD, Godrej Soaps Research Centre, Pirojshanagar, Eastern Express Highway, Vikhroli, Bombay-400 079, India.

ABSTRACT

Two fairly widespread **Jatropha** species, **J. curcas** and **J. gossipifolia** and one common ornamental type **J. podagrica** showed marked interspecific phenological and chemobotanical differences. The botany and chemistry of **Jatropha** species, the industrial applications and the research imperatives for further improvement of the cultivars are identified.

INTRODUCTION

Jatropha Linn. (Euphorbiaceae) a genus, native of tropical America, occurs in its wide diversity throughout tropical to subtropical parts of Asia and Africa. Nine species have been reported from India[1]. Of these, in the order of distribution, **J. curcas, J. gossipifolia** and **J. glandulifera** are the predominant species mostly found in semi-wild state, and occasionally cultivated in hedgerows as farm fences. (Other closely related species are **J. nana** and **J. multifeda. J. pendurifolia** and **J. podagrica** are common ornamental types). **Jatropha curcas** Linn. has variously been considered as a potential oil-seed plant for a variety of non-edible purposes[2-5]. Lately, in the hunt for alternative liquid fuel resources, seed-oil from **J. curcas** known as 'curcas oil', was identified as one of the possible substitutes for Diesel engine oil[6-7]. However, till date, no regular seed collection from the existing semi wild or cultivated bushes is done for any such end-uses in the country as against the commercial plantings in Brazil or Ghana[4,8]. Considering that India still pays large import bills for both vegetable oils as well as petroleum crude and its byproducts, the relevance of commercial exploitation of oilseeds like **Jatropha** needs no emphasis[9].

Little has been done on the botanical exploration of Jatropha species in India. Previous attempts on the evaluation of **Jatropha** seed oils are far from satisfactory as evidenced by the greatly differing values relating to fatty acid composition[1,3,5,10]. Furthermore, the characterisation of 'curcas oil' and the utility research to decide on its alternative industrial applications, and the overall plant productivity and yield figures to develop economically feasible husbandry of **Jatropha** has not received due attention. In the present paper, results from initial studies on chemobotany of three phenologically distinct species, **J. curcas, J. gossipifolia** and **J. podagrica**, are described. While details on the characterisation of 'curcas oil' have been attempted, some future research imperative on crop improvement and application research are also outlined.

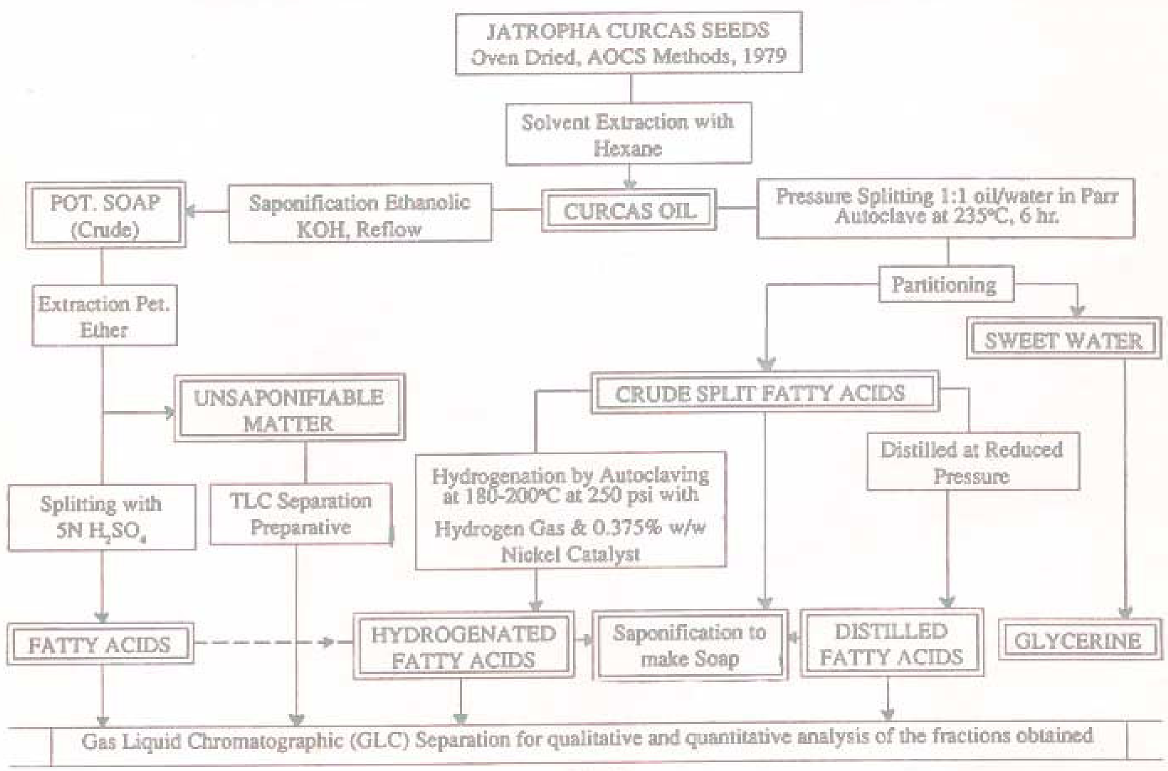

Fig. 1

Schematic diagram of the 'Curcas Oil' characterisation procedures and analytical methods followed.

MATERIALS AND METHODS

Jatropha curcas seeds were collected from the states of Gujarat (near Sarat), Tamil Nadu (Coimbatore), Maharashtra (Palghar, Pune, Phaltan) and West Bengal (BSI, Calcutta); J. **gossipifolia** collection from Gujarat (Baroda), Maharashtra (Palghar) and Andhra Pradesh (Hyderabad, Rajahmundri) and J. **podagrica** from local Bombay gardens. These collections were grown in the experimental plots at Godrej Soaps Research Centre, Bombay for initial evaluation. Regular examination of phenological data and seed yields were made. Seeds were analysed for seed and oil characteristics following AOCS methods[11]. The identification and quantification of the fatty acid profile of the seed oil was carried out by Gas Liquid Chromatography (GLC) after esterification to their methyl esters, using 20 per cent DEGS and 2m S.S. Column. The high seed bearing lines identified from **Jatropha curcas** provenances were isolated for further evaluation of (a) economically important biological traits and (b) qualitative assessment and further characterisation of curcas oil as per the schematic description given (Fig. 1). Further, the unsaponifiable matter from 'curcas oil' was analysed by TLC and also by GLC as their Trimethyl Silyl derivatives using flame ionization detector and following operating conditions: glass column (1.0 x Mx2 mm i.d.) packed with 3% OV-101 on Chromosorb WHP; injector and detector temperature at 350°C; column temperature was programmed from 200°C to 300°C @ 4° per min. and maintained at 300°C for 10 min. Nitrogen was used as a carrier gas.

RESULTS AND DISCUSSION

The comparative phenological details of 3 **Jatrophas** are presented in Table 1. Leaf morphology was identified

Table 1

Comparative Chemobotanical Data on three Jatropha Species from India

Plant Characteristics	Jatropha Curcas Linn	Jatropha Gossipifolia Linn.	Jatropha Podagrica Hook
Plant habit	Large shrub, 3-4 m max. ht.	Gregarious bushy shrub 0.5-2 m. ht.	Ornamental potted plants may grow upto 1.5 m ht.
Leaf	10-15 cm x 7.5 x 12 cm, broadly ovate, cordate, acute, palmately 3 or 5 lobed, glaborous, petiole 20-24 cm long;	0-12 cm x 18-20 cm, palmately 4-5 lobed, at first shining brown, later turning green, petiole shorter in length, petiole and leaf blade covered with glandular hairs;	25-30 cm x 20-30 cm, peltate, long petiolated, glaborous, glaucous 3-5 lobed, lobe subovate with margins devoid of serration;
Flower	Yellowish green in loose panicles of cymes;	Dark red, crimson or purplish in glandular corymbose cymes;	Orange-red or scarlet on terminal long-stalked cymes;
Fruit	a. 25 mm long, ovoid initially green turning yellow and finally dark brown, breaking on drying into 2-valved cocci; contains 3 seeds, at times 2 seed due to one abortive ovary, but 4 seeded fruits are also not uncommon;	a. 9 mm long, 3 lobed, truncate at both ends, bursts open on maturity to disperse mostly 3 seeds;	a. 15 mm long, ovoid, initially green turning brownish on maturity, bursts open to disperse 2-3 seeds to a good distance.
Seeds	Ovoid-oblong, dull brownish black, weight of 100 sundried seeds 56.340 gram.	Greyish-red, with a carnule, weight of 100 sundried seeds 5.239 gm.	Reddish grey to dark brown with a carnule, weight of 100 sundried seeds 15.827 gms.
Seed dormancy	Good mature seeds may germinate within a week of harvest, do not lose viability even on 1-2 year storage;	Good mature seeds may germinate within ten days of harvest, do not lose viability upto 2 yrs. storage in a dry place;	Good mature seeds can germinate within a week of harvest, do not lose viability even upto an year's storage in a dry place;
Seed yield	One kg per bush per year and upto 5 m tons per hectare per year;	100 gm per bush per year and upto 500 kg per hectare per year;	10 gms per plant per year and upto 400 kg per hectare per year.
Seed composition	Seed shell to kernel ratio by dry wt. 44 : 56;	Seed shell to kernel ratio by dry wt. 35 : 65;	Seed shell to kernal ratio by dry wt. 25 : 75;
Seed oil	Oilcontent in kernel 47-52 per cent and in shell 3 per cent, of light yellowish colour, IV 92.42; Sap. Val. 191.26; hydroxyl value 4.28 and unsaponifiable Matter 1.539 percent	Oil content in kernel 29 percent and in shell 3.5 percent; of yellow colour; IV 134.50; Sap. Val. 192.10; and Unsaponifiable Matter 1.102 per cent.	Oil content in kernel 54 percent and in shell 4 percent; of yellow colour; IV 137.50; Sap. Val. 193.32; and Unsaponifiable Matter 0.940 percent.

as the most distinctive feature of the species identity. (Fig. 2). Other phenological distinction is the presence of glandular hairs all along the leaf margins, petiole and blade in **J. gossipifolia.**

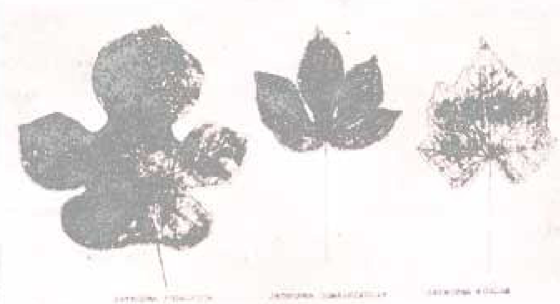

Fig. 2

Leaf impressions of three **Jatropha** species (reduced to the same scale).

Economic traits: Under unirrigated conditions, leaf foliage emergence, flowering and fruiting in **J. curcas** is restricted to two seasons, i.e. the summer and winter season; the seasonal behaviour is less pronounced in **J. gossipifolia**, while **J. podagrica** which is more or less evergreen bears flowers and seeds almost round the year. In J. curcas, out of the two bearing seasons, the summer flush was normally the poor yielder, mainly due to poor flowering and poor ratio of male to female floral inflorescenes. The other two species did not show such seasonal variation in the floral and fruit bearing.

Seed Yield: On the basis of yield data from the experimental plots, none of the provenances of J. **gossipifolia** and J. **podagrica** yielded more than 100g/bush/year and 10g/plant/year with 1m x 2m and 0.5m x 0.5m plant to plant and row to row spacing for the respective species. Under identical growing conditions, few promising provenances of **J. curcas** yielded one kilogram seeds per bush in the 2nd year of planting spaced 1m x 2m plant to plant and row to row apart.

Jatropha seed: J. **curcas** seeds are larger in size and weight, but with poorer kernel to shell ratio of less than 3:2 and kernel oil content of 47 per cent as against kernel to shell ratio of 3:1 and kernel oil content of 54 per cent in J. **podagrica**. However, unlike most other **Jatropha** species, J. curcas fruits are non-shattering type and this makes curcas seed collection easier.

Pest and disease incidence: J. **curcas** which on intensive cultivation under irrigated conditions behaves more or less like an evergreen, showed infestation of powdery mildew on leaves and fruit, fungal leaf spots and even susceptibility to thrip and mite attack. On the other hand, J. **gossipifolia** and J. **podagrica** remained completely free of any visible fungal or insect pest infestation.

The initial biological assessment leads us to believe that with better selection procedures, high yielding lines could be isolated in **Jatropha curcas,** a species with higher yield potential. Of the other two species, J. **podagrica** has good genetic resource potential for economic traits like higher kernel to shell ratio, higher kernel oil content and together with J. **gossipifolia** for resistance to diseasess and insect pest damage. This will call for more non-conventional plant improvement approaches to break the inter-species incompatibility barrier, e.g., by protoplast fusion techniques. Since the available phyto-resources have little to offer, as evidenced by later details, attempts to generate greater genetic variability within J. **curcas** by induced mutagenesis also holds some promise.

Jatropha **seed oil fatty acid composition:** A comparative account of the fatty acid profile of 3 species is presented in Table 2. While the ratio of saturated to unsaturated fatty acid content in **J. curcas** is 24:76 against 15:85 in J. **gossipifolia** and J. **podagrica;** 18 carbon fatty acids (stearic, oleic and linoleic) form the bulk (a. 85 per cent) of the total fatty acid content in all 3 species. However, oleic to linoleic ratio of 44:31 in J. **curcas** differs greatly from 15:65 in J. **gossipifolia** and J. podagrica. The maximum 16 carbon fatty acid content of 17.4 per cent was in J. **curcas**.

None of the **Jatropha** species showed any significant variation within the provenances for the fatty acid composition. However, unlike J. **podagrica**, the other 2 species showed a definitive influence of the season of harvest on the fatty acid composition, especially the degree of unsaturation within C18 fraction (Table 3). **J. curcas** which was studied in more detail showed variation arising due to stage of maturity determining the stage of fruit harvest, as well as variation due to season of harvest of seed lots from the same bushes. Such variability could partly explain the disparity in the composition, as cited variously in the literature. However, for J. **gossipifolia,** even after screening a number of provenances, the authors fail to explain values arrived at by Hussain et al[10]. Further, it may be added that none of the **Jatropha** species examined by us or by many other workers elsewhere (see the ref. list) show the total absence of linoleic acid ($C_{18}=2$). The above study is also indicative of the fact that

Table 2

Comparative assessment of Fatty acid profile (percent composition) of three Jatropha species

Fatty Acids (FA)	Jatropha curcas	Jatropha gossipifolia	Jatropha podagrica
Total Saturated FA	24	15	15
Total Unsaturated FA	76	85	85
GLC Profile:			
Lauric	—	—	—
Myristic	0.07	0.52	0.50
Palmitic	16.27	8.56	10.58
Stearic	7.34	6.43	4.28
Arachidic	0.26	0.60	0.26
Palmitoleic	1.16	0.37	0.42
Oleic	43.87	15.89	14.58
Linoleic	30.74	65.32	66.63
Linolenic	0.30	—	—

Table 3

Effect of seasonality and stage of maturity on the fatty acid composition (%) of two Jatropha species

Major fatty acids (as % of total fatty acid profile)	Jatropha Curcas Linn.				Jatropha Gossipifolia Linn.	
	Summer Harvest		Winter Harvest		Summer harvest	Winter harvest
	Slightly immature seeds	Mature sundried seeds	Slightly immature seeds	Mature sundried seeds		
Palmitic	13.493	16.229	13.648	15.392	8.558	8.8
Palmitoleic	0.913	1.487	1.065	1.251	0.17	0.52
Stearic	10.902	5.255	10.429	6.409	6.432	9.37
Oleic	49.364	35.972	47.441	36.601	15.885	24.37
Linoleic	24.541	40.577	25.746	38.456	65.322	54.5

chemobotanical variability available in any of the 3 species for specific utilities of the seed oils, is of very low significance. However, the induced mutagenesis and utilisation of biological materials from the South American gene pool may be better means of producing the desired results.

'Curcas Oil': Kernel oil of **Jatropha curcas** was pale yellow in colour while the whole-seed-oil had a darker colour, but could easily be bleached with activated earth. With fairly good content of oleic and palmitic acid, **prima facie**, curcas oil' can as such be used for laundry soaps.

Curcas oil on splitting yielded (a) good quality fatty acids and (b) glycerine. Distillation of the split fatty acids (Fig. 1) yielded more than 82 per cent light coloured, heat stable fatty acids. The following colour changes for distilled fatty acids were recorded after a treatment of 100°C ± 5°C for 2 hrs:

$$\left.\begin{array}{ll}\text{Initial colour} & 0.6Y + 0.3R \\ \text{Final colour} & 0.1Y + 0.7R\end{array}\right\}\text{ in 1'' cell}$$

Composition of distilled fatty acids was: Palmitic — 15.2, Palmitoleic — 1.3, Stearic — 6.5, Oleic — 41.4 and Linoleic — 33.3 per cent. Distilled fatty acids appear to be useful for premium grade toilet soaps.

Hydrogenation of crude split fatty acids was fast, smooth (without any poisoning effect) and complete. It required only 0.375 per cent (w/w) nickel catalyst (20% nickel content) to obtain hydrogenated fatty acids of I.V. — 3.0. However, partial hydrogenation of split fatty acids to any desirable I.V. is also possible. The hydrogenated fatty acids on further distillation yielded more than 80 per cent very light coloured fatty acids with Palmitic — 20.3, Stearic — 76.8 and Oleic Acid — 2.4 per cent. Hydrogenated fatty acids could be a very valuable industrial raw material.

The unsaponifiable matter, about 1.6 per cent of the curcas oil contains 60 per cent phytosterols (of which more than 80 per cent β-sitosterol) and 20 per cent alcohols (of which more than 26 per cent C_{10} alcohol). In addition to a variety of applications in pharmacological synthesis, β-sitosterol is also valuable plant growth stimulant.

'Curcas oil' also contains some non-lipaceous active principles which reduce the ammonia volatilization losses from urea and inhibit nitrification process on soil application like the neem oil principles[12]. This could open yet another possibility of its use in development of slow release nitrogenous fertilizers.

As a substitute for No. 2 diesel, Ishii and Takenchi[13] found transesterified curcas oil and its blends to be fuel efficient, superior in thermal efficiency, producing less black smoke, but higher HC and CO concentration as compared to No. 2 diesel, and suited well for farm diesel engines.

Jatropha curcas oilcake is rich in nitrogen when compared to other commonly available organic manures. However, because of its toxicity, the oilcake, as such, cannot be used as an animal feed, but it is a good fertilizer comparable to neem cake in its use[5].

Jatropha curcas latex has been used in a number of local Ayurvedic Pharmacopoeia. Researchers[14] at Beltsville, Maryland, USA, have found anticancer properties for Jatrophone, an active principle from curcas latex.

Jatropha curcas green tender leaves are a useful feed for tasar silk worms and the plant holds promise to sustain a small scale silk industry in rural India. **Jatropha curcas** also repells field rodents when planted on farm fences as hedgerows.

Jatropha curcas has high capability of regeneration, is amenable to pruning operations and thus makes its husbandry much easier in more hostile as well as under intensive cultivational practices. Hence, with proper isolation, evaluation, selection and improvement of 'curcas cultivars', a sustainable oilseed plantation can be made feasible using a whole tree utilisation concept.

ACKNOWLEDGEMENTS

Authors are grateful to Mr. Nadir B. Godrej, Director Godrej Soaps Pvt. Ltd. for his encouragement and keen interest in this project; Mr. M. S. Thakur, Vice-President (R & D) for necessary facilities. Our colleagues in the sections of Agriculture and Oil-Fat Chemistry for their timely help in carrying out this work and Mrs. Venkatesh for typing the manuscript.

REFERENCES

1. Anon. The Wealth of India, Raw Materials — Vol. 5 (H-K); Pub. CSIR, New Delhi, India (1959), 293.
2. Anon. In : V. T. Godin and P. C. Spensley (Ed.) Oils and Oilseeds, TPI Crop and Product Digest, No. 1, Pub. TPI, London, UK (1971) P. 107.
3. Anon. In : Tree Borne Oilseeds — a resource for gainful employment. Pub. Directorate of Non-Edible Oils & Soap Industry, KVIC, Bombay, India (1978), p. 37.
4. Cherry, M., World Crops, 31(2), 75 (1979).
5. Viswanadham, R.K., Thirumala Rao, S.D., Narayana, C., I.O. & S.J. 203, April (1969).
6. Raina, Ashok K. Jatropha curcas Linn. Proc. Bio-energy Conference, New Delhi, India, 1984 p. 114-117
7. Minoru, O. and Takeda, Y. Interim Report on the study of Jatropha curcas oil as a substitute for Diesel Engine Oil, Industrial Finance Corporation of Thailand, Bangkok, (1981) p. 14.
8. Cruz, N.D. Da and Forni Martens, E.R., Agronomico, 37(2), 109 (1985).
9. Raina, Ashok K., In : Srivastava, et al (Ed.) Plantation Crops — Opportunities & Constraints Vol. 1 Pub. Oxford & IBH, N. Delhi, India (1986) p. 211.
10. Ahmad, M. S., Ahmed, S.M., Ahmed, M., Osman, S.M. and Hussain, S.R., J. Oil. Tech. Assn. India 14, 61(1982).
11. Anon. (1979) Official and Tentative Methods of the American Oil Chemists' Society, 3rd ed., Pub. AOCS, U.S.A. 1979.
12. Shinde, J.E. and Hulegur, B.F., Bull. Indian Soc. Soil Sci., 13, 138 (1984).
13. Ishii, Y. and Takenchi, R. Trans. ASAE, 30 605 (1987).
14. Duke, Jim, Contributions on Neo-tropical Forests to Cancer Research. Pub. Eco. Bot. Lab. (USDA) BARC-East, Beltsville, Maryland, U.S.A. (1982).