International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 6, September-October 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Potentiality of Petrocrops for Future Energy and Biochemical

Dr. Anshu Rani

Associate Professor in Botany, SMCC Government College, Aburoad, Rajasthan, India

ABSTRACT

Calvin was first who studied about petro crops. Some plants or algae produce hydrocarbons, ethanol etc which can act as actual and potential sources of energy, these plants are known as petrocrops. Some of the examples of petrocrops are *Calotropis procera, Jatropha curcas* etc.

Petro plants accumulate the photosynthetic pigment and have lactiferous canals which secrete milky latex in their stem which forms petroleum in the flowering plants. These plants are good for the environment as the ethanol produces very less carbon monoxide. Petrocrops are quick energy conserving plants that are grown for production of Petrochemicals. These plants yield petroleum containing compounds as a substitute of petrol. Calvin did his study on Euphorbiaceae plants. Calvin also gave a Calvin cycle regarding the study of chemical reactions carried out in photosynthetic plants. The world demand of petroleum products has been growing at a rate higher than the discovery of new resources in the last decade. If the demand rates sustain and if they are possibly met with by increased production, it is estimated that the worlds' presently recoverable oil sources would be exhausted before 2020. Thus, the search for alternative sources of hydrocarbons or similar chemicals has been started the world over in right earnest. Several directions are being explored. An important one amongst these is the possibility of deriving hydrocarbon type substances from renewable plant materials. The best solar energy converting machine available today is the green plant. Most plants store their energy as carbohydrates in the form of sugar or polymerised sugar (cellulose), but some plants store their energy as fully reduced carbon in the form of hydrocarbons. The most common example is the rubber tree, *Hevea brasiliensis* which produce hydrocarbons with a high molecular weight range (500,000 to 2,000,000). There are number of green plants which systhesize reduced constituents, having lower molecular weight than Hevea. If a source plant can be found, developed and cultivated which gives a liquid sap containing hydrocarbon type molecules or molecules predominantly of a type and size range which can be converted to liquid hydrocarbon type fuels. It offers a good route for deriving liquid fuels in quantities sufficient to replace petroleum derived fuels.

How to cite this paper: Dr. Anshu Rani "Potentiality of Petrocrops for Future Energy and Biochemical" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-6, October 2021, pp.1914-1920, URL: www.ijtsrd.com/papers/ijtsrd47743.pdf

IJTSRD47743

KEYWORDS: *petrocrops, biochemical, potentiality, future energy, petrochemicals, plants, fuels, resources*

INTRODUCTION

Fuel is one of the mankind's primary necessities, and it is indispensable, both in the home and industry. The use of wood as a fuel for heating and cooking dates from the earliest times. The more popular fossil fuels (principally coal, petroleum, etc.) and even the nuclear fuels (principally uranium, thorium, deuterium, and lithium) would be exhausted over a period of time because of over exploitation. Forests will ultimately remain our last reservoir[1,2]. However, over the centuries, forest resources have been endangered in a number of ways as a result of man's unrestrained activities such as overgrazing, indiscriminate lumbering, agricultural operations and burning.

With the depletion of fossil fuel reserves on one side and their ever-increasing demand for our expanding industries and thirdly the threat of global warming through rising levels of greenhouse gas emissions, the world has seen in recent years a paradigm shift over handling the question of our energy needs. The search for viable alternative energy sources has become more urgent than ever before and the countries are turning back to nuclear energy, geothermal, solar power, wind and water power, etc. Another option available for us is to tap the potentials of 'Energy Crops' or 'Energy Plantation or plants producing hydrocarbons or utilisation of vegetable oils - both edible or non-edible - although renewable but would they be able to keep in check the carbon dioxide emission level!

As gasoline prices soar and the supplies dwindle, a shift from food production to fuel production (alcohol) has come to be encouraged in many affluent countries. Of all the energy crops, sugarcane (*Saccharum officinarum* L.) is known to give the highest alcohol yield per hectare. The combination of high alcohol yield coupled with the built-in source of fuel, in the form of bagasse, to operate the distillery, makes sugarcane exceedingly attractive candidate as an energy crop. The 'energy canes' developed in Puerto Rico and Cuba not only provide approximately the same amount of sugar per hectare as the standard cane, but also produce about three times more bagasse, making the whole industry self- supporting in energy.[3,4]

Review of Literature

In tropical and subtropical countries, *Jatropha curcas* is a potential biofuel crop. Among the oil-bearing tree species, *Jatropha* is desired due to its drought hardiness, rapid growth, easy propagation, low cost of seeds, high oil content, small gestation period, wide adaptation, production on good and degraded soils and the optimum plant size that makes the seed collection more convenient. The drought resistant plant, that can grow on lands not suited for agriculture and both improve the environment and supply raw material for local communities is attractive for resource-poor farmers. The advantages of the *Jatropha* as a plantation crop, Cultivation scope, scope of Jobs for all, Distribution of *Jatropha* curcas, Botanical description of *Jatropha curcas*, Flower and seed setting, Soil and climate conditions required for the cultivation, Varieties suitable for the cultivation, Propagation methods, Seed rate, Planting of seeds and cuttings in field, Aftercare, Canopy management (Pruning and trimming), Manuring, Intercropping, Diseases, Harvesting, Economic life, Yield, Precautions for achieving the Higher productivity and profitability, Some immediate problems that may crop up to a farmer's mind, Suggested measures to be taken immediately, [5,6]Research need, Best Agronomic practices to increase seed yield, *Jatropha* growing feasibility by Targeted Growing Areas, Future Thrust Area for yield enhancement, Commercial use of *Jatropha* plants such as used as live fence, *Jatropha* for enrichment of soil, as a non-conventional energy crop. India is deficit of non-edible oil and imports a large quantity of oil seeds to meet the demand. The need for increasing import and higher prices of petroleum has created the need to explore new avenues for tapping Tree Borne Oil Seeds (TBOS) in India in sizeable quantities.[7,8] *Jatropha* is worth mentioning in this context. The Planning Commission has already outlined a programme with the Union Government to launch nation-wide *Jatropha* plantation with a view to generate environment friendly bio-fuels to tap non-conventional sources of energy. The programme is currently being implemented by the Ministry of Petroleum and Ministry of Rural Development with the assistance of Indian Oil Corporation (IOC) in collaboration with the Indian Railways.

According to a report from National Bank for Agriculture and Rural Development (NABARD) on the potential of Tree Borne Oil Seeds (TBOS) in India, the concept of Biodiesel and its ongoing application has opened a new era of petro-crops or bio-fuel on one hand and growing demand of indigenous cosmetic and paint industry on the other. Moreover, the byproducts like glycerine and other pharmaceutical products during the oil refining process and oil cakes make this sector attractive from ecological, employment and economic point of view as well. It is also pertinent to mention that the working group report of Planning Commission, GOI has recommended nearly 23 Lakh Hectares *Jatropha* plantations to achieve five per cent replacement of petro-diesel, by bio-diesel in the coming years.[9,10]

The oil import bill of India, which was Rs 84, 000 crores in the year 2001-02, is likely to increase at the rate of 6 to 7 per cent annually because of the total requirement of Petroleum in India, 72 per cent is imported. The Planning Commission report have come out with a study, which reveals that import of crude oil is expected to go up from 85 million metric tones per annum to 147 million metric tones per annum correspondingly increasing the import bill from USD 13.3 billion to USD 15.7 billion in the coming years. Therefore the increasing prices of petrol and diesel has necessitated the use of tree borne non-edible oil such as *Jatropha* as an alternative to fuel and as an additive. The Planning Commission has estimated that 10 per cent replacement of petroleum fuel by bio-fuel would also help save Rs 8, 400 crores annually in foreign exchange.

Planning Commission has identified 200 districts in 17 potential states as suitable for *Jatropha* plantation on the basis of availability of wasteland, rural poverty ratio, below poverty line census and agro climatic conditions suitable for *Jatropha* plantation. The potential of *Jatropha* can be gauged from the fact that it can be grown in arid and semi-arid lands without little or no care. It is ideally suited for drought prone and dry areas. *Jatropha* has a strong anti-erosion quality which helps in protecting the soil cover. *Jatropha* has a life span of 40 years and starts producing seeds in two years time. Jastropha is found across the country and finds its use in tanning products, dyes, bio fertilizer, soaps, waxes, pest control products and has great medicinal properties.[11,12]

The following is the list of petrocrops

Petro Crop	Family Name
Agave americana	Agavaceae
Allemanda vathartica	Apocynaceae
Nerium odorum	Apocynaceae
Tabernaemontana coronaria	Apocynaceae
Thevetai nerifolia	Apocynaceae
Wrightis tomentosa	Asclepiadaceae
Aclepias curassavia	Asclepiadaceae
Calotropis gigantica	Asclepiadaceae
Ceropegia tuberosa	Asclepiadaceae
Cryptostegia grandiflora	Asclepiadaceae
Pergularia daemia	Asclepiadaceae
Copaifera longsdorfii	Euphorbiaceae
Euphorbia lathyris	Euphorbiaceae
Hevea Brasiliensis	Euphorbiaceae
Jatropa curcas	Euphorbiaceae
Pedilanthus thithymaloides	Euphorbiaceae
Aloe vera	Liliaceae
Sansevieria sps.	Liliaceae
Artocarpus integrifolia	Moraceae
Argemone mexicana	Papaveraceae
Pedalium murex	Pedaliaceae
Pittosporum resinferum	Pittosporaceae
Madhuca indica	Sapotaceae
Mimusops elengi	Sapotaceae
Vitis quadrangularis	Vitaceae

Technically, energy plantation means growing selected species of trees and shrubs which are harvestable in a comparably shorter time and are specifically meant for fuel. These plantations help provide wood either for domestic or industrial purposes.

The energy plantations provide almost inexhaustible renewable sources of energy which are local and independent of unreliable and finite sources of fuel. The total time constant for each cycle is 3-8 years only.

Materials and Methods

Petrocrops may provide a renewable source of petroleum in the future. The use of low boiling nonpolar (hexane) and polar (methanol) solvents may afford nonpolar and polar biocrudes respectively by successive extractions. However, further successive extraction of spent residue obtained in anthracene oil, quinoline, or liquid paraffin may afford recovery of biopolymer biocrude. These biocrudes may be hydro treated to yield liquid fuels. With fast disappearing petroleum reserves renewable resources like biomass are of great significance. Petrocrop, *Calotropis procera* is a wild shrub and does not compete with food and fodder crops for land. This paper presents an investigation on enhancement of hydrocarbon extraction from *Calotropis procera*. [13,14]An extraction yield of 8% has been obtained with toluene, as solvent. Increase in extraction to 11.5% has been achieved by modification of design of conventional "Soxhlet extractor". Further enhancement in extraction has been achieved by pre-treatment of the biomass with alkali or acid. Pre-treatment results in extractive or hydrolytic breakdown of plant structure and hence exposes hyrocarbons to solvent attack. Alkali pretreatment of ground biomass resulted in much higher extraction. So it was studied in further detail with more alkalies of varying strength. An enhancement from 8% to 18% has been achieved by pre-treatment with IN sodium hydroxide.

Discussion

There are some species of certain families which accumulate the photo-synthetic products (hydrocarbons) of high molecular weight (10,000). They are commonly known as petroplants or petroleum plants. In 1979, Dr. M. Calvin of the University of California reported for the first time the collection and use of photosynthetically produced hydrocarbons from the plants (Calvin, 1979). Furthermore, he suggested it as a substitute for conventional petroleum sources. Calvin and coworkers screened most of the plants of Euphorbiaceae, especially *Euphorbia* (containing 2,000 species) which reduce CO_2 beyond the carbohydrates. The petroplants have lactiferous canals in their stem and secrete a milky latex. The latex can be either continuously tapped like *Hevea* latex and stored or extracted from the biomass by using the organic solvents. The product rich in hydrocrackable hydrocarbon is called as 'biocrude'. Biocrude yields about 70.6% energy; out of which 22% as kerosene and 44.6% as gasoline. About 400 plant species, belonging to different families are known which grow in different part of the country. It is hoped that petroplants can yield petroleum more than 40-45 barrel/acre.[15,16]

Hydrocarbon from Higher Plants

Euphorbiaceae has been extensively screened, which has shown the fruitful results. In addition, the most useful plant families to be investigated are Asclepiadaceae, Apocyanaceae, Leguminosae, Sapotaceae, Moraceae, Dipterocarpaceae, Compositae, etc.

However, the members of Euphorbiaceae possess high amount of hydrocarbons.

Hevea Rubber

Rubber plant, *(Hevea brasiliensis)* commonly known as *Hevea* rubber is the principal source of rubber which is restricted in distribution in South-East Asia. This plant meets one third of total world demand of rubber. The synthetic rubber elastomers from petroleum have not replaced the demand of natural rubber, due to its low cost build up, resilience, elasticity and good performance in automobiles and aeroplanes. Rubber is tapped from stem of trees by making incision and collecting the latex from it. The latex is further processed to get rubber.

Euphorbia

In Italy, Euphorbia Gasoline Rifinery was set up to tap vegetative gasoline. *Euphorbia lathyris* is an annual herb and *E. tirucalli* is a perennial one. *E. lathyris* can produce 20 t dry matter/ha/yr. Chemical analysis of this plant in organic solvents revealed that heptan extract and ether soluble fraction constituted about 8% terpenoid extract.

By using zeolite catalyst, it could be converted into high grade transportation fuel. Of the 85% converted materials, about 10% is in the form of natural gas and 75% in gasoline-like fractions. Calvin and co-workers estimated that 10 tonnes of biomass could yield 5.3 barrels of crude extract convertable to gasoline.[17,18]

Plants producing hydrocarbons

Plant group/families	Common names	Botanical names
Algae (Chlorophyta)	-	Botryococcus sp. Chlorella pyrenoidosa
Euphorbiaceae	Hevea rubber	Hevea brasiliensis
	Rubber plant	Euphorbia abyssinica
	Rubber plant	E. resinifera, E. lathyris,
	Sehund	E. tirucalli
Compositae	Guayule	Parthenium argentatum
	Russian dandelion	Taraxacum koksaghyz
Asclepiadaccae	Aak	Calotropis procera
Leguminoseae	-	Copaifera langsdorfii, C. mutijuga
	Samprani	Hardwickia pinnata
Dipterocarpaceae	Gurjun	Dipterocarpus turbinatus
Myristicaccae	-	Dialynthera otoba
Pittosporaccae	-	Pittosporum resiniferum

Features of Energy Plantations

The attractive features of energy plantations are:

- Good amount of heat content of wood
- Wood low in sulphur and non-polluting
- Ash from burnt wood is a valuable fertiliser
- Raising plantations in erosion-prone lands helps to reduce soil erosion
- Help in rural employment generation

Significance of Energy Plantations

Energy plantations are the plants planted only for use as fuel. The woody plants have been used since ancient times to generate fire for domestic and industrial purpose. In recent years, to meet the ever growing demand of energy, plantation of energy plants is been encouraged. We are all aware that trees are cut in many of the forest belts of India like Gangetic plains, Siwalik region and foot-hills of Himalayas.

In terms of fuel wood production, India is the biggest, but the per capita fuel wood production is very low. In India, people of hill area hardly get fire-wood plants and they have to go to interior of forest to collect wood-falls. Also introduction of technologies developed for plains is not achievable in these areas.[19,20]

For example, they cannot be motivated to use solar cooker, because of being solely traditional and religious. Even gobar gas plant cannot be useful in hills, due to low temperatures. Therefore, renewable source of energy is highly desirable for survival of population in hills and for reducing the pressure on forests. And thus, energy plantation has got great support in our country.

For obtaining good amount of biomass, afforestation and forest management government has started many plans like social forestry, silviculture and agro-horticulture practices in waste and barren lands. These programmes include growing of drought resistant, salt resistant, pollutant resistant and high density energy plantations (HDEP) in waste and barren

The technique used in high density energy plantations, HDEP is the practice of planting trees at close spacing. Here the trees grow rapidly due to struggle for survival. It provides fast and high returns with many opportunities of permanent income and employment.

Social Forestry: Energy plantation and power programme

Plantation through social forestry has been highlighted by the Government of India to meet the demand of fuel and fodder in the rural areas. Social forestry will definitely decrease the ever increasing pressure on the forests. Through social forestry, trees are planted along road sides, canals, railway lines and waste lands in villages.

The following must be considered while selecting plant species for energy plantations:

- ➢ The species should be local. This helps for better climatic and soil adaptation.
- ➢ Species should show rapid growth and high coppicing ability.
- ➢ The species should also produce additional products like fruits, seeds, fodder and green manure apart from fuel wood.
- ➢ The species must have hard wood.
- ➢ The species must have low requirement of water and fertilizer.
- ➢ The species must have ability to increase the soil quality.
- ➢ The species also should have high calorific value of wood.[21,22]

Results

Till now, much emphasis has been given on crop plants. At present, there is need to encourage cultivation of petroplants, in waste lands. There is need for joint efforts of botanists, phytochemists, engineers, economists, and geneticists to make successful research on these lines.

Guayule and Russian Dandelion

Guayule *(Partheniuum argentatum)* and *Taraxacum koksaghyz* of family compositae are sources of rubber. Guayule a shrub is indigenous to North Central Mexico and South-West U.S.A. Guayule generally grows in arid, semi-arid and desert areas. The U.S. Government encouraged the cultivation of this plant after World War II to reform the economy of the country. It can tolerate temperature ranging from 32 - 38°C, and can grow in Indian conditions.

Like *Hevea,* guayule contains cis-polyisoprene and identical physical properties. There is need to develop technologies for the production of hydrocarbon to be used as alternative fossil fuel. *Aak (Calotropisprocera)*

Aak (Family Asclepiadaceae), a shrub of 1-2.5 meters in height, occurs in hot and dry parts of India on waste dry places, river beds, roadsides and forest clearings. It secretes latex which causes irritation to skin. Latex contains high amount of extractable hydrocarbons. The ratio of C, H, O in the hexane extract has been found as 78.03%, 11.22% and 10.71% respectively. The ratio of C and H is similar to crude oil, fuel oil and gasoline. Hydrocarbon yield and energy value of C. *procera* are comparable to those of *E. lathyris.* Therefore, this plant can be used as a substitute of petroleum. Researches on it are being done at the Central Arid Zone Research Institute, Jodhpur.

In India, cultivation of petroleum plants needs to be encouraged and suitable technologies should be developed for extraction of crude oil to be used as fuel. NBRI (Lucknow), and Indian Institute of Petroleum (Dehra Dun) have started preliminary screening programme of such plants. Over 400 plant species are to be tested for growth conditions, habitat performance, biomass yield and hydrocarbon content. [23,24]

Algal Hydrocarbons

Dead algal scum of *Botryococcus braunii,* an unicellular alga of Chlorococcales of green algae, contains about 70% hydrocarbons. Percentage of hydrocarbon may vary. The algal hydrocarbons closely resemble the crude oil, and therefore, can be used as a good source of direct production of hydrocarbons.

B. braunii grows in fresh or brackish water as well as in tropical and temperate zones. When in full growth, it becomes apparent in water as the small dots. The alga appears in two forms, as far as pigmentation and structure of synthesized hydrocarbons are concerned. The first form is of green color and contains linear hydrocarbons with an odd number of carbon atom (25-31) low in double bonds. The second form of alga is red in color which contains hydrocarbons with 34-38 carbon atoms and several double bonds, the 'botryococcenes'. Significance of these two forms are not known. This alga is composed of proteins, carbohydrates, and lipids, the percentage of which varies. However, it has proved to be a source of hydrocarbons. As a result of metabolic activity, the hydrocarbons are synthesized during growth phase of the alga. In addition, *Chlorella pyrenoidosa,* a fresh water alga, is known to be converted into hydrocarbons. Hydrogenation is done in a steel reactor at high temperature (> 400°C) and pressure (12,000 p.s.i., pound per square inch) in the presence of a catalyst (cobalt molybdate). The alga is suspended in a mineral oil in the reactor. Hydrogenation is carried out for about one hour. Consequently, 50% of algal biomass is converted into oil with a little amount (12-14%) of a byproduct, ammonium carbonate. Oil is a clear golden liquid which is separated from the reactor, blended with light gas oil in refineries and processed before its use.

Hydrocarbon is accumulated as globules on outer walls and cytoplasm of the cells. On cell wall, a major portion of hydrocarbon (95%) is located, whereas a: small amount (0.7%) of it is present within the cells. Hydrocarbons are recovered from the cells by centrifugation. The cells are again added in the fresh culture medium as inoculant. For the production of hydrocarbons in high amount, it is necessary to increase the algal biomass. However, it could be achieved by characterizing the culture medium and light and shade conditions for its growth and biomass production.

Conclusions

There are some plants whose products can be used in place of fossil fuel (petrol and diesel). These plants belong to plant families such as Apocynaceae, Asclepiadaceae, Euphorbiaceae, Sapotaceae, Urticaceae, Compositae etc.

Some plants are as follows:

- Euphorbia Lathyris.
- Calotropis procera.
- Jatropha curcas
- Copaifera langsdorffii
- Pedilanthus macrocarpus

Energy is the key factor for the economic growth of any nation and India is no exception. In spite of increasing availability of energy, there is always need for more. This is the reason which has prompted the world countries to develop alternative sources of energy like geothermal, solar and wind. Moreover we must use the available coal reserves sustainably.

In this context, crops producing hydrocarbons are very important. Petroplants accumulate photosynthetic products like hydrocarbons of high molecular weight. In 1979, M. Calvin of the University of California reported the collection and use of photosynthetically produced hydrocarbons. He suggested them as a substitute for conventional petroleum sources.

Most of the plants belonging to the family Euphorbiaceae, Asclepiadaceae, Anacardiaceae, Asteraceae, Caprofoliaceae and Lamiaceae are promising petroplants. *Euphorbia lathyris* of family Euphorbiaceae is considered as most suitable petrocrop containing more than 5% oil and polymeric hydrocarbons.[25]

References

[1] Achten WMJ, Mathijs E, Verchot L, Singh VP, Aerts R, Muys B 2007. Jatropha biodiesel fueling sustainability?. Biofuels, Bioproducts and Biorefining 1(4), 283-291. [1] doi:10.1002/bbb.39 The Jatropha Archives

[2] Achten WMJ, Verchot L, Franken YJ, Mathijs E, Singh VP, Aerts R, Muys B 2008. Jatropha bio-diesel production and use. (a literature review) Biomass and Bioenergy 32(12), 1063-1084. [2]

[3] Janick, Jules; Robert E. Paull (2008). The Encyclopedia of Fruit & Nuts. CABI. pp. 371–372. ISBN 978-0-85199-638-7.

[4] "Jatropha curcas (jatropha)". www.cabi.org.

[5] "Indian Biofuels Market Rides a Crest as Demand Surges from the Indian Transport Sector". Archived from the original on 12 October 2008.

[6] Satyendra Nath Mishra. 2014. Design of Resource Use: case of jatropha based biodisel in India. Journal of Rural Development. 33(1). 1–13. Online link "Archived copy" (PDF). Archived from the original (PDF) on 7 April 2014. Retrieved 2014-03-31.

[7] "Centre For Jatropha Promotion – Promoting farming for future fuel – Growing Diesel Fuel Plant". Retrieved 15 November 2006.

[8] "India Inc eyes jatropha farming in a big way". Business Line. 2 September 2005. Retrieved 15 November 2006.

[9] "Asia turns to plants for fuel: Governments seek crops to cut oil dependence". The Baltimore Sun. Archived from the original on 18 June 2006. Retrieved 8 July 2006.

[10] Ajayebi, Atta; Gnansounou, Edgard; Kenthorai Raman, Jegannathan (2013). "Comparative life

cycle assessment of biodiesel from algae and jatropha: A case study of India". Bioresource Technology. 150: 429–437. doi:10.1016/j.biortech.2013.09.118. PMID:24140355.

[11] Bikash, Singh (20 October 2006). "Kalam backs jatropha farming in NE". The Economics Times. Times News Network. Archived from the original on 7 April 2020. Retrieved 7 April 2020.

[12] Pratap, Ram; Jain, A. K.; Saxena, Manish (December 2017). "Studies on Production and Characterization of Bio Diesel from Jatropha" (PDF). International Journal of Engineering and Applied Sciences (IJEAS). 4 (12): 75. ISSN 2394-3661. Retrieved 7 April 2020. In one of his speech, he said that India is having about 600, 000 km² of wasteland out of which over 300, 000 km² is suitable for cultivation of Jatropha plants.

[13] "Biofuels and India: The story so far" (Blog post). Energy Zone Powered By the Economic Times. Times Internet Limited. Archived from the original on 4 February 2012. Retrieved 1 April 2020.

[14] Rocha, A. S.; Veerchamy, M; Agrawal, V. K.; Gupta, S. K. (2010). "New opportunities and challenges: conference proceedings". In Pudlowski, Zenon J. (ed.). 1st WIETE Annual Conference on Engineering and Technology Education New Opportunities and Challenges Pattaya, Thailand 22 and 25 February 2010 (PDF). Melbourne: World Institute for Engineering and Technology Education. p. 94. ISBN 9780980766400. Retrieved 1 April 2020.

[15] "Rlys to plant jatropha for captive use — Minister seeks private participation". The Hindu Business Line. Kolkata: The Hindu Group of Publications. 19 October 2005. Archived from the original on 27 March 2006. Retrieved 7 April 2020.

[16] "RIL enters bio-diesel farming". zeeu. Archived from the original on 9 December 2006. Retrieved 15 November 2006.

[17] "Indian State to Plant 160 Million Jatropha Plants in Quest for Biofuel Self-Sufficiency". Retrieved 4 December 2006.

[18] Barta, Patrick (24 August 2007). "Jatropha Plant Gains Steam in Global Race for Biofuels". The Wall Street Journal. Retrieved 1 April 2008. Until recently, B. K. Nagendrappa didn't care much at all about jatropha, an ugly wild green shrub that thrives in India. Now, the coconut grower hopes to plant as many as 12 acres (4. 9 ha) of the stuff on his land near Bangalore.

[19] http://www.lablandbiodiesel.com Labland Biodiesel. Retrieved 21 June 2008

[20] "HPCL, Maharashtra tie up for bio-diesel venture". The Hindu Business Line. Retrieved 8 July 2006.

[21] "Maharashtra to offer 300 km² to private sector for jatropha cultivation". The Hindu Business Line. Retrieved 8 July 2006.

[22] "Pune take the lead in using bio-diesel for running 105 buses". Indiadaily.com. Archived from the original on 23 March 2007. Retrieved 8 July 2006.

[23] "The Govind Gram Vikas Pratishthan (GOGVIP)". GOGVIP. Archived from the original on 8 October 2007. Retrieved 23 August 2007.

[24] "Ahmednagar NGO set to launch biodiesel project". Business Line. Retrieved 23 August 2007.

[25] Godse, Sameer (6 February 2013). "Jatropha spells success for Ahmednagar NGO". Business Standard. Pune: Business Standard Private Ltd. Archived from the original on 7 April 2020. Retrieved 7 April 2020.