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BIO FUELS

Dependence on foreign sources of energy has always been a bane for the Indian economy. It is the single biggest drain on the foreign exchange reserves of the country and the uncertainty in the prices of international crude has always kept Indian government and planners on tenter hooks. An increase of $1 per barrel of crude oil prices adds $425 million to our oil import bill. As India imports 70% of the oil it uses, the country has been hit hard by the increased cost and uncertainty and so is exploring other energy avenues.

Transport sector remains the most problematic sector as no alternative to petroleum based fuel has been successful so far. Fossil fuels especially petroleum diesel (HSD) will continue to dominate the transport sector in the future but their consumption can be minimized by implementation of Bio-Diesel program. Research has shown that vehicular emissions are the source of air pollution and have adverse implications on health and air quality. Lead, carbon monoxide, nitrogen oxides, particulate matter and hydrocarbons together with the unavoidable production of carbon dioxide are the harmful components of an internal combustion engine's exhaust gases.

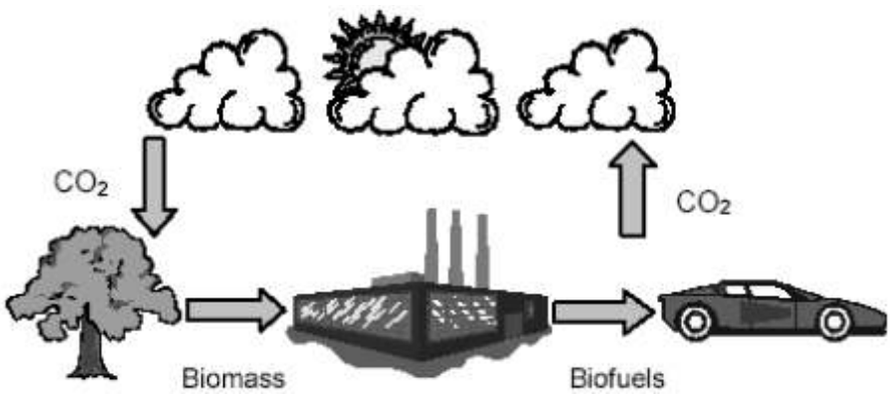
Bio Fuel

Biofuels is a generic term and includes a large number of fuels. We are, however, concerned, at the present moment, with biofuels that will be used in the transport sector. So Biofuels can be defined as a renewable liquid fuels coming from biological raw material and have been proved to be good substitutes for oil in the transportation sector. As such biofuels ethanol and biodiesel- are gaining worldwide acceptance as a solution to environmental problems, energy security, reducing imports, rural employment and improving agricultural economy.The production of biofuels utilizing presently under-utilised resources of land and hence providing nutrients to soil, checking soil erosion and thus preventing land degradation. The search for alternative fuels has been on for long. Bio fuels offer an attractive opportunity to conserve and economize use of conventional fuels like petrol and diesel. Bio fuels are being used the world over as admixtures with conventional fuels at levels that do not require modifications of internal combustion engines.

The oil extracted from plants such as Jatropha, Pongamia, etc., can be processed into bio fuel. In fact, Jatropha is a very hardy plant that grows well in semi arid conditions and is not browsed by cattle or attacked by pests. The process involved in producing bio fuel from these plants can generate employment especially in the rural areas.

Source: http://www.biospectrumindia.com

Biofuel as 'climate-natural' fuels



Source: http://www.ecn.nl/docs/library/report/2003/c03008.pdf

The Government of India has adopted a National Policy to promote bio-fuel usage

Why Biofuels?

Bio fuels are renewable, hence they can supplement hydrocarbon fuels, assist in conservation fossil fuels, reduce green house gases as well as mitigate their adverse effects on the climate. Both ethanol and bio diesel, in addition to being renewable and indigenously available, also help in improving the environment by its characteristics like reduced emission of carbon monoxide, hydrocarbons, particulate matter and non-toxic gases. Bio diesel extracted from non-edible oils also enhances the lubricity of diesel, and thus improves the efficiency and durability of the engine. Bio fuels are non toxic, biodegradable and nonflammable with very high flash points. Bio-fuels have the following advantageous properties:

- Bio fuel yielding trees having high oil-bearing capacity
- Renewable and alternative energy sources
- Easy to develop and use.
- Low-cost and not a-very-high-tech route, therefore, can be readily implemented, Environmentally safer and compatible
- Biodiesel provides more lubrication than petroleum diesel
- Bio-degradable, non-toxic and free of sulphur and aromatic compounds, therefore, no SO_x emissions.
- Bio-fuel is an ideal synergistic partner for oxidation catalytic converter and reduces CO2 emissions by 78 per cent when compared to conventional diesel fuel.
- Bio-diesel is an oxygenated fuel with O_2 content of about 10 percent and therefore gives better emission characteristics in term of CO, Hydrocarbons, Particulate matter.
- Also, Bio-diesel has a higher Cetane number, ensuring low noise and smooth running, during engine combustion.

Biofuels Worldwide

Ethanol is a well established oxygenate, and is used as a transport fuel across the world. About 68 percent of alcohol produced globally is used for this purpose. In Brazil alone, around 12 billion liters of ethanol per year is produced from sugarcane, which is more than the Indian consumption of petrol. In the USA, about 8 billion liters of ethanol per year is produced mostly from corn. Many other countries, including Canada, Spain, France, Sweden, Thailand, China, and Australia also produce and use ethanol.

In European countries, sugar beet is preferred instead of sugarcane for production of ethanol as sugar beet has certain advantages over sugar cane. Sugar beet has lower cycle of crop production, higher yield, high tolerance of wide range of climatic variation, low water and fertilizer requirement. The yield of ethanol is also higher per year per unit of land.

History of alternative fuels

Before the introduction of gasoline as a motor fuel in the late 1800, vehicles were often powered by what are now considered alternative fuels. For example, illuminating or coal gas (a form of methane or natural gas) was used in early prototype internal combustion vehicles in the 1860s. Electricity, stored in lead acid batteries, was a popular energy source for vehicles from as early as the 1830s until the 1920s.

In the 1880s, Henry Ford built one of his first automobiles and fuelled it on ethanol, which was often called "farm alcohol" because it was made from corn. His early Model Ts were designed with an adjustable carburettor to allow them to run on alcohol fuel. Liquefied petroleum gas (commonly called propane) has been used as a transportation fuel for more than 60 years.

Alternative fuels are substantially non-petroleum and yield energy security and environmental benefits. Alternative Fuel Vehicles (AFVs) are vehicles that run on fuels other than petroleum products. They have been with us in one form or another for more than one hundred years. Only recently, however, have they become more common place.

In those early years of the horse-less carriage, naturally formed gasoline was expensive and often sold by the pint in pharmacies; it was also used as a cleaning solvent. New petroleum refining technologies (thermal cracking and eventually catalytic cracking), however, produced gasoline inexpensively; and gasoline, because of its high energy content, became the fuel of choice for internal combustion engines.

Source: Society of Indian Automobile Manufacturers - http://siamindia.com

- In addition, the by-product resulting after extracting bio fuel is an excellent source of nitrogen rich organic fertilizer.

Economic Impacts Biofuel production:

- Generates new demand for agricultural commodities and increases the commodity prices
- Utilizes the unused resources
- Increases farm income
- Improves the balance of trade
- Save foreign exchange and
- Creates new jobs

Apart from the various benefits, the program on biofuel will result in greening of waste land, drought proofing, energy security for the country and promotion of organic farming. It will also result in utilization of waste and fallow land in addition to the land on agricultural field boundaries, along public roads and railway tracks.

Sources: *1) http://petroleum.nic.in/ch_11.pdf*

2) ***Hosein Shapouri****. United States Department of Agriculture, Office of the Chief Economist.*

Types of Biofuels :- Ethanol and bio-diesel are the two bio-fuels which are being looked upon as the potential fuels for surface transportation.

1) Ethanol:

Ethanol is a clear, colorless liquid with a characteristic, agreeable odor. In dilute aqueous solution, it has a somewhat sweet flavor, but in more concentrated solutions it has a burning taste. Ethanol (CH3CH2OH) is a group of chemical compounds whose molecule contains a hydroxyl group, -OH, bonded to a carbon atom. Ethanol is made from sugar beet, cane, wheat, molasses and wood. It can be produced in two forms hydrated and anhydrous. Hydrated ethanol has a purity of 95% suitable for blending with an ignition improver, or as a 15% emulsion in Diesel. A second stage refining process is needed to produce anhydrous ethanol (100% purity) for use in blending with petrol.

Presently, ethanol is the most viable route to energy independence for India as, it is a bio-fuel, and will also help in achieving sustainable development and economic freedom. Being an oxygenate, it helps fuel burn more completely reducing CO emissions by 15 to 20%. Higher octane number allows it to achieve higher engine thermal efficiency. Higher volumetric efficiency is possible because of high latent heat of vaporisation. Fewer carbon-to-carbon bonds and higher octane number make it possible to reduce benzene content (used as an octane booster presently). However disadvantages of ethanol are:

- It is corrosive in nature in that it badly affects metallic and non-metallic parts but it can be controlled by the use of certain commercially available additives.
- Higher latent heat of vaporization causes cold and hot start problems.
- It emits aldehyde concentrations but can be controlled by suitable formulation of catalytic converters.
- It requires large fuel tank capacity due to lower calorific value.

Volumetric Efficiency

In internal combustion engine design, volumetric efficiency refers to the efficiency with which the engine can move the charge into and out of the cylinders. More correctly, volumetric efficiency is a ratio (or percentage) of what volume of fuel and air actually enters the cylinder during induction to the actual capacity of the cylinder under static conditions. Therefore, those engines that can create higher induction manifold pressures - above ambient - will have efficiencies greater.

Source: http://En.wikipedia.org/wiki/Volumetric_efficiency

Sugar Development Fund

The Government has amended the Sugar Development Fund Act, 1982 to enable loans to be given from the Sugar Development Fund to any sugar factory or any unit thereof for the production of anhydrous alcohol or ethanol from alcohol. This amendment made in May 2002, has made available financial assistance on easy terms to sugar factories for setting up facilities for producing ethanol. The Government has also framed the rules in this regard. It is expected that more sugar factories would be encouraged to produce ethanol from alcohol after availing financial assistance from the Sugar Development Fund.

Emissions outcomes for higher ethanol/petrol blends:

Hydrocarbon emissions decreased with higher blends:

- o at 10% ethanol, HC emissions decreased by about 18%.
- o at 20%, HC emissions decreased by about 22%.
- o at 40%, HC emissions decreased by 45%.

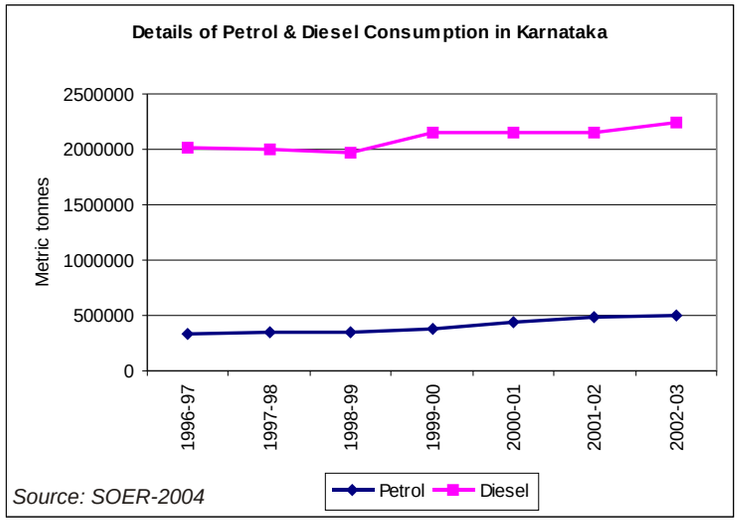
NOx emissions increased with higher ethanol volume:

- o at 10%, NOx emission increase was about 10%.
- o at 20%, NOx emission increase was about 14%.
- o at 40%, NOx emission increase was about 20%.

CO emissions were lowered by higher blends:

- o at 10%, CO reduced by about 18%.
- o at 25%, CO reduced by over 30%.
- o at 40%, CO reduced by over 40%.

Source: Report on "Bio-Fuel" Planning commission GOI.



Source: SOER-2004

Bio-diesel emissions compared to conventional diesel

Emissions	B100	B20
Regulated Emissions		
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
Nox	13%	2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polycyclic Aromatic Hydrocarbons (PAH)**	-80%	-13%
NPAH (Nitrated PAHs)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%
Life-Cycle Emission		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

B100-100% biodiesel, B20-20% biodiesel and 80% petrodiesel
*Estimated from B100 results. ** Average reduction across all compounds measured
***2-nitroflourine results were within test method variability

Source: Report on "Bio-Fuels" Planning commission GOI.

2) Bio diesel:

Biodiesel is a renewable, non-polluting fuel produced mainly from vegetable oils and fats. Chemically, it is known as free fatty acid methyl ester (FAME). It can be used in normal diesel engines and it has all the ecological advantages over the mineral diesel, as it neither pollutes nor adds to the global warming. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. As bio-Diesel has properties similar to petroleum diesel fuels, it operates in compression ignition engine and essentially requires very little or no engine modifications.

In developed countries like the US, Australia, Germany, France, etc., biodiesel is being extracted from rapeseed, sunflower, soybean, etc., which are essentially edible in India. Biodiesel is also being increasingly used since the last decade, particularly in Europe. Capacity building in this sector too is gathering momentum, especially in the USA. Countries like Germany, France, and Austria have fairly large biodiesel programs, with many others showing a growing interest in this sector. India has vast resources of non-edible/wild seeds from which oil can be derived to develop biodiesel depending upon the potential of specific seeds in the locality. Instead of the edible oil seeds biodiesel derived from non-edible oil seeds can be used in existing designs of diesel vehicles without any substantial modification.

From Table of Bio diesel emission Vs conventional diesel, it is clear that biodiesel gives a distinct emission benefit almost for all regulated and non-regulated pollutants when compared to conventional diesel fuel but emissions of NOx appear to increase from biodiesel. NOx increases with the increase in concentration of biodiesel in the mixture of biodiesel and petrodiesel. This increase in NOx emissions may be neutralized by the efficient use of NOx control technologies, which fits better with almost nil sulphur biodiesel than conventional diesel containing sulphur. It may also be noted that emission of NOx also varies with the different family of feedstocks for biodiesel. Moreover, the problem of increased NOx emission can be effectively tackled by retarding the fuel injection timing; emissions of nitrogen dioxides

are either slightly reduced or slightly increased depending on the duty cycle and testing methods. However hydrogen fraction stays the same or is increased. Therefore, biodiesel works well with new technologies such as oxidation catalysts.

At present there are around 1050 oil extraction units registered in the state (non-edible) with the extraction capacity varying between 10 to 100 tons per year (Source: EMPRI), which is largely used for domestic needs. Farmers are already using bio diesel for pump sets and tractors in some parts of the state. Government is promoting cultivation of non-edible oilseeds on farmlands and wastelands. The state will also be carrying out extensive plantation of non-edible oil seed producing tree species, in the watershed areas through departments of watershed development, forest and agriculture.

The development of bio-fuel from non-edible oilseeds would also contribute to strengthening the rural economy by creating opportunities for rural employment and increasing income of farmers.

Toxicity issues of Biodiesel:

Biodiesel does not present any problems of toxicity as discussed below:

- o It is bio-degradable.
- o Biodiesel is non-toxic. The acute oral LD50 (lethal dose) is greater than 17.4- g/Kg-body weight.
- o Very mild human skin irritation. It is less than the irritation produced by 4% soap and water solution.
- o There is no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on biodiesel (20% Rapeseed Methyl Easters 80% diesel).

Source: Report on “Bio-Fuel” Planning commission GOI.

Substitution of Triglycerides(vegetable oils) to diesel fuels

Triglycerides (vegetable oils/animal fats) and their derivatives may be considered as viable alternatives for diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. The problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance and make them compatible with the diesel fuels through processes like pyrolysis, microemulsification, dilution and transesterification.

Pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. The pyrolyzate had lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values and they are compatible with diesel fuels.

Micro-emulsification is the formation of microemulsions (co-solvency) which is one of the potential solutions for solving the problem of vegetable oil viscosity. Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersions.

Dilution of vegetable oils can be accomplished with such materials as diesel fuels, solvent like ethanol.

Transesterification is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis. This process is used to reduce the viscocity of triglycerides. Transesterification also called alcoholysis.

Status of Non-edible oil seeds in Karnataka

A study carried out by Environment Management & Policy Research Institute shows that there exists a great potential in the state with respect to the non-edible oil seeds like pongamia, neem, and mahua. The survey of non-edible oil yielding trees like pongamia (honge), neem(bevu) and mahua (hippe) on the farmland, forest land and wastelands was

Biodiesel: First trial run on Train

The Indian Railways is experimenting with the new eco-friendly “bio diesel” fuel to run passenger trains. The first successful trial run of a superfast passenger train was conducted on December 31, 2002 when Delhi-Amritsar Shatabdi Express used five per cent of "bio diesel" as fuel. Indian Railways would be able to not only save on its rising fuel bill but also control the pollution level. Sulphur and lead emissions came down significantly when biodiesel was used. If biodiesel is used, to the extent of 10 per cent mixture with the conventional diesel, Railways' annual fuel bill of Rs. 3,400 crores for using diesel could be reduced by nearly Rs. 300 crores to 400 crores per annum. Ultimately, the percentage of bio diesel would go up to 15 per cent as per the accepted global norms. The new green fuel is extracted from the seeds of the `Jatropha' plant and Indian Oil is now engaged in laboratory tests of bio diesel.

taken up in 17 districts which represent all the agro-climatic regions of the state.

From the survey it was found that around 50% of the honge seed produced in the state is commercial traded while the rest is consumed in domestic sector. Similarly, in case of neem, 65% of the total seed produced is traded for commercial exploitation. The gap between seed production potential and the quantity traded is enormous. This wide gap is mainly due to huge demand of seeds for the local (domestic) consumption. Also, low opportunity cost of seed collection as compared to daily wage rate is also responsible for the low seed collection assuming that on an average 25% oil is produced from pongamia and other oilseeds, 15% from neem, while for Mahua it is 50%. The non-edible oil production in the commercial market was assessed by collecting data from the District Industries Centre (DIC). There are around 1050 oil extraction units registered in the state (non-edible) with the extraction capacity varying between 10 to 100 tons per year. However very small number of oil extraction units are currently working.

Oil content in different crops

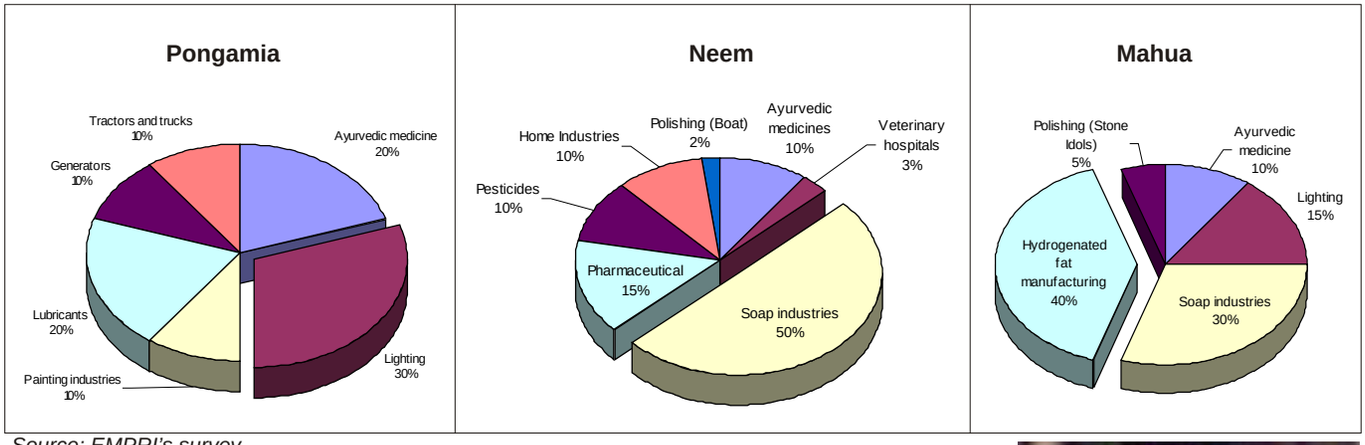
Crop	kg oil/ha
Cotton	273
Soybean	375
Safflower	655
Sunflower	800
Rape seed	1000
Jatropha	1590

Source: Report on "Bio-Fuel" Planning commission GOI.

OIL BEARING TREES FOR BIO DIESEL

There are many tree species which bear seeds rich in oil having properties of excellent fuel and which can be possesses into diesel substitute. In Karnataka the important commercial non-edible oil yielding trees are, Pongamia pinnata, Azadirachta indica, Madhuca longifolia and Schlichera oleosa, Garcinia indica , Calophyllum inophyllum and many more. The oil obtained from such seeds is chiefly used for manufacture soaps, candles, paints, varnishes, linoleum, lighting and for medicinal purposes.

Usage of Pongamia, Neem & Mahua oil for various purposes



Source: EMPRI's survey

KARANJA (Pongamia pinnata Syn.P.glabra, Derris indica)
Family-Papilionaceae
English-Indian beach, poong oil plant
Hindi-Karanja
Kannada-Honge, Hulgul, Rakta honge

Pongamia pinnata is a leguminous tree i.e. nitrogen fixing (NFTS) which produces seeds containing 30-40% oil. It is often planted as an ornamental and shade tree. This species is commonly called pongam, karanja, or a derivation of these names. 'Pongamia' name is derived from Tamil name of the plant viz. ' pongam' or ' pungam'. In latin " pinnata' means 'feathered' and glabra' means without hairs. It is found to grow in areas with annual rainfall ranging from 500 mm to over 2500 mm. It is drought

resistant. It occurs in a wide range of soil conditions, sandy and saline, clayey soils, alkaline soils, but it does not grow well on very dry sand. Best growth has been observed on deep sandy loams with abundant moisture. It can occur in areas with poor as well as good drainage. It does well with full overhead light in its early stages. Natural reproduction is profuse by seed and common by root suckers. Bark is thick grey mottled with brown dull yellow inside. It is indigenous through out India from Himalayan foot-hills to Kanyakumari. Other than India it grows in Seychelles, Pacific Islands, Sri Lanka, Malaysia, China, and Tropical Australia.

Fruits have a viability period of one year with a germination percent of 60-80% and seed number varies between 810-1410 per kilogram. Seed yeild an average of 25-30% of yellowish brown oil. Honge is a leguminous tree yielding non-edible oil which can be used as biodiesel i.e. substitute of diesel to run engine at the same efficiency. Traditionally, it has been used to burn household oil lamps and for curing skin diseases.

Chemical Content of the oil: Furano flavones, demethoxy kanugin, (-)-isoconchocarpin, chromenochalcone, glabrachalcone.

Uses: Wood used as firewood. Leaves are used as green manure and also it keeps away termites. Seeds yield rich oil, used in herbal-soaps, traditional medicines for skin infections and rheumatic pains. The oil is used to cure the skin diseases like scabies, herpes, Leucoderma and cutaneous diseases. Internally it is used in dyspepsia with sluggish fever. The oil is used for making soaps, illumination and leather tanning. In Ayurveda, oil is used for oedema, poisoning, piles, etc. In Siddha, the oil is used for cure glandular swelling, eczema, ear disease, fainting, abdominal disorder, snake bite poisoning, cough, skin eruption, veneral diseases and pain.

NEEM / MARGOSA TREE (Azadirachta indica)
Family- Meliaceae
English-Neem Tree, Margosa Tree, Indian Lilac
Hindi-Balnimb, Nimb, Neem
Kannada- Bevu, Bevinamara,Olle bevu

Neem is one of the most widely cultivated and naturally occurring species in Karnataka. It is a sacred tree, known to Indians since ages, seen near temples and in villages. 'Azadirachta' is a Persian name; and 'Indica' means 'of India' in Latin. It is distributed all over the country from arid to moist tropics, but is common in drier parts and deciduous forests. It grows on a variety of soils, from sandy to clayey including black cotton soils. Neem grows well on flat ground with high sub-soil water level and good drainage. It tolerates temperature ranging from 0 C to 40 C. It also possesses certain amount of drought hardiness and thrive in extremely low rainfall of (130 mm annually). It is medium to large sized tree, 15-20 m in height, with a clear bole of 7 m having greyish to dark grey tubercled bark. This tree is identified by its imparipinnate shining deeply serrate leaves. Leaves are compound, imparipinnate, leaflets sub-opposite, very oblique at base. Young leaves appear throughout the year at intervals, but chiefly at the beginning of the spring in March. Leaves are bitter in taste, tender leaves are pale green in colour. Scented white flowers abundance on axillary spikes during March-April. Flowers are small, white, or yellowish white in axillary panicles, elongate. Fruits one seeded drupes 1 to 2 cm long with woody endocarp, greenish yellow when ripe. Seeds ellipsoid, cotyledons thick, fleshy and oily. Fruits ripen from June to August and posses a germination capacity of 70-90% for a very short period. Kernel yields an average of 25-30 percent of oil. The oil is yellow in colour and bitter in taste. It is said to have medicinal properties and is used in skin diseases. It is extensively used in soap industry. It is also used by the poorer classes as an illuminant.

Uses: All parts are used in traditional medicines. Tooth paste is prepared from the leaves. Seed oil is used for treating leucoderma, skin infections, intestinal and ringworms, scabies, chronic malarial fever, liver disorder, cough, dyspnoea, anorexia, distaste, polyuria, wounds, poisoning, eye diseases, rejuvenator, epilepsy, vomiting, eczema, jaundice and leprosy. Oil is also used as illuminants and for manufacture of soaps. Oil-cake makes good manure, and keeps away pests. Gum from the trunk is stimulant and tonic. Bark, fruits used in fever and as tonic. Leaves keep off pests, used against fevers, small pox, chicken pox. Timber is hard and used in buildings, carts, ship-building, agricultural

implements, furniture.

Chemical content of Oil: Limonoid, Mahmoodin, Protolimonoid, Naheedin, Tetranortriterpenoids, Azadirone, Epoxyazadirone, Nimbin, Gedunin, Azadiradione, De acetylnimbin, 17-hydroxy azadiradione, Nimbocinol, 17-Epinimbocinol.

JATROPHA CURCAS

Family- Euphorbiaceae
English- Purging Nut, Physic nut
Hindi-Bagberenda
Kannada- Adalu haralu, Kaadu Haralu

Jatropha has been considered as most suitable for bio-diesel as the oil yields per hectare is among the highest of tree borne oil seeds. Its oil, being a potential substitute to diesel, it grows on gravely, sandy or saline soils and also on the poorest stony soils and rock crevices. Its water requirement is extremely low and withstands long periods of drought by shedding most of its leaves to reduce transpiration loss. It retains soil moisture and improves land capability and environment. It is easy to establish and grows relatively quickly. Requires minimal after-plantation care, lesser gestation periods, not grazed by animals even during the times of drought, strengthens its case for promotion in wastelands. It is able to ensure reasonable production of seeds with very little inputs. The seeds are easy to collect as the plants are not very tall and are available during the non-rainy season, which facilitates better collection and processing. The plant starts giving seeds in a maximum period of 2 years after planting. Yields vary from 0.5 to 12 t/yr based on soil and rainfall conditions. Per 100 g, the seed is reported to contain 6.6 g H_2O, 18.2 g protein, 38.0 g fat, 33.5 g total carbohydrate, 15.5 g fiber, and 4.5 g ash (Duke and Atchley, 1983). The oil cake left behind is excellent organic manure, the bio mass of Jatropha curcas enriches the soil and it can also be put to other uses. Various parts of the plant are of medicinal value, its bark contains tannin and flowers attract bees.

CALOPHYLLUM INOPHYLLUM

Family- Clusiaceae
English- Alexandrian laurel, Borneo Mahagony
Hindi- Sultanachampa, Surpunika
Kannada- Honne, Hoohonne

Calophyllum inophyllum is primarily a tree of the seashore and adjacent lowland forests. It grows in areas with annual rainfall ranging from about 1000 to 5000 mm and maximum temperatures ranging from 30 to 35°C. Humidity variations recorded in areas of its natural distribution are 60 to 100 percent in July and 60 to 80 percent in January. It is generally described as slow-growing tree. The tree grows in a wide variety of soils, from nearly pure coastal sands to clay, and is capable of growth on degraded and poorly drained sites. It can be found right at the edge of the sea, where it may be exposed to high winds, sea spray, and brackish water tables.

The fruit (a drupe) is green, round, and typically 2 to 4 cm in diameter including a thin (3 to 5 mm) layer of pulp, the shell, and the single large seed. Fully mature fruits are yellow- or red-brown and wrinkled. Seeds can be collected from trees by picking individual fruits or lopping off branches with pruning poles. The thick, dark green oil extracted from the seeds is used in a number of products, including oil for lighting, medicines, and body and hair grease (Little and Skolmen 1989, Neal 1965).

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