

Harnessing potential of selected underutilized bio energy crop *Pongamia pinnata*



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Applied Environmental
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www.aerfindia.org

**Harnessing potential of selected
underutilized bio energy crop**
Pongamia pinnata

A report for

**Global Partnership Initiative for Plant Breeding Capacity
Building (GIPB)**

**And International Bio- energy Platform and cross sectoral
Collaboration of
the FAO Interdepartmental Working Group on Bio Energy**

By

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Section I

Introduction

Rudolf Diesel in 1911 run the engine on peanut oil and claimed it run exceptionally well....

1. Background

Worldwide interest and activity in biofuels has grown dramatically in the last few years. Governments, private investors, environmentalists are among those who have begun to push for stronger support for biofuels as a way to meet a range of economic, social and environmental goals. The world today consumes approximately ten times as much energy per person as it was 100 years ago. The world energy consumption is expected to increase 2.3% per year for the next few years. The severe depletion of fossil fuel resources in future may lead to stalemate and push the planet into the darkness. Apart from this, the burning of fossil fuels also is disturbing the planet ecosystem by causing green house effect, global warming, ozone depletion, and acid rains.

1. 1 Global Scenario

The global markets for biodiesel are entering a period of rapid, transitional growth, creating both uncertainty and opportunity. The first generation biodiesel markets in Europe and the US have reached impressive biodiesel production capacity levels, but remain constrained by feedstock availability. In the BRIC nations of Brazil, India and China, key government initiatives are spawning hundreds of new opportunities for feedstock development, biodiesel production, and export" said Biodiesel 2020 author Will Thurmond.

With near record oil prices, the future of biofuel made from plant material is of keen interest worldwide. Global biofuel production has tripled from 4.8 billion gallons in 2000 to about 16.0 billion in 2007, but still accounts for less than 3 percent of the global transportation fuel supply. About 90 percent of production is concentrated in the United States, Brazil, and the European Union (EU). Production could become more dispersed if development programs in other countries, such as Malaysia and China, are successful.

The leading raw materials, or feedstocks, for producing biofuels are corn, sugar, and vegetable oils. While rapid expansion in biofuel production has raised expectations about potential substitutes for oil-based fuels, there have been

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growing concerns about the impact of rising commodity prices on the global food system. According to the International Monetary Fund, world food prices rose 10 percent in 2006 because of increases in corn, wheat, and soybean prices, primarily from demand-side factors, including rising biofuel demand. The Chinese Government put a moratorium on expanded use of corn for ethanol because of rising feed prices and is promoting other feedstock that do not compete directly with food crops, such as cassava, sweet sorghum, and Jatropha (an oil-bearing plant originally from South America). It is therefore all the more important to look at non edible feedstock like Pongamia pinnata as a potential source of bio fuels world wide.

1.2 New Era of High Oil Prices Attracts Investment in Biofuels

The rise in oil prices is the most important factor boosting the competitiveness of alternative fuels, including biofuels. The unprecedented 6-year rise in oil prices has prolonged opportunities for efficiency gains, stimulated energy conservation, and generated increased supply from traditional and alternative energy sources. While these adjustments may eventually lower oil prices, most forecasts do not show real prices falling below \$50 per barrel.

Previous periods of high oil prices were short. Prices tended to rise very sharply, usually induced by military conflict, peaked in a matter of weeks or months, and then declined sharply. Following these price spikes, the rapid decline in petroleum prices made it difficult to sustain alternative fuel programs and reduced incentives for consumers to curb their use of petroleum products.

Unlike previous high-price periods, the current oil market is driven by strong demand-side factors. These factors include robust economic growth and rising oil demand from rapidly growing middle-income economies, where consumers are demanding a higher standard of living and exhibiting big appetites for energy. Almost two-thirds of recent global growth in oil demand has come from China and other middle-income economies.

1.3 Bio Fuels in India

After the oil crisis of the 1970s, the need for alternative fuel and energy sources still remains a concern. India produces only about 30% of its annual crude oil requirements, heavily relying on imports. It is therefore obvious that the oil import bill is a big dent on the Indian economy. In India, the interest in biofuels has grown dramatically since last decade. The demand for petroleum products in the country has risen from a modest level of 3.3 MT in 1950-51 to 65.5 MT in 1994-

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1995. The current demand is more than 100 MT per year which create oil pool deficit of more than 15, 000 crore rupees.

The chief rationale for biofuels in India is energy security. Better environmental performance, greening of wastelands and creation of new employment opportunities - are seen as some of the other advantages of biofuels. The two biofuels that are currently the focus of attention are (i) bio-ethanol and (ii) bio diesel.

Diesel forms the primary fuel source for the transport and industrial sector. This demand is set to increase at about 5.6% per year. As crude oil sources diminish and demand escalates, the need to substitute diesel without major alternations to existing diesel-based technology is a prerequisite. The use of vegetable oil as a diesel substitute proved feasible, as diesel engines have been run on vegetable oils in the past. As early as 1911, Rudolf Diesel, the inventor of the diesel engine, claimed to have run a diesel engine on peanut oil. He further stated that the engine ran exceptionally well. The use of vegetable oils to run diesel engines is therefore the most practicable alternative to diesel, as it does not require any technological changes to ongoing systems, unlike other non-conventional fuel and energy sources that have failed to replace conventional regimes.

This proves to be an opportunity for India to gain fuel and energy self-reliance through the development of its diverse oil seed bearing plant resources. In response, the Planning Commission of the Government of India decided on promoting bio-fuels on a national scale as one of its policy decisions within the 'National Auto Fuel Policy'. The National Oil Seeds and Vegetable Oil Development (NOVOD) Board was formed in order to develop and strengthen the oil seed producing capacity of the country. A number of feasibility studies were undertaken in order to select and promote oil seed bearing species on a national scale. Two front-runners for bio-diesel yield were *Jatropha curcas* and *Pongamia pinnata*, both species suited to plantation on wastelands throughout the country. Consequently, the Ministry of Non-Conventional Energy Sources has targeted the plantation of the two species on 22 million hectares of wasteland on a national scale. Although an audacious goal, such an extensive programme requires definitive planning based on sound research input. This project was developed in order to provide the required input to promote the *Pongamia* based system through resource assessment methodologies firmly grounded in natural resource management.

Since the potential of these two species as feedstock for bio diesel production has been popularized there are efforts all over the globe to cultivate them on large scale .However these species are not known to plant breeders conventionally and still to establish as usual cash. Many of the underutilized or

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neglected plant species are grown or used very little or only locally used. But these species have great promise for contributing to sustainable energy production, livelihoods and rural development.

Within the last decade, the term Biodiesel is almost synonymous with *Jatropha*. However in a biodiversity rich country like India, many wild indigenous species that produce oil and could be tapped as potential sources of biofuel. Such species include *Pongammia pinnata*, *Calophyllum inophyllum*, *Madhuca latifolia*, *Schleslera oleosa*, *Sageria laurifolia* and *Ceasalpinia crista*.

These native species are still found in various parts of the country. Some species like *Pongammia* and *Calophyllum* were traditionally used for oil production and the oil was used for meeting local energy needs. Later with the easy availability of fossil fuels; the village level seed collection and oil production eventually disappeared and people started cutting these trees for fuel wood. However success in domestication and production of underutilized bioenergy crops is dependent on wide range of preconditions. Most basic of these is the understanding of genetic resources available through natural selection over time and from selections of adopted material by farmers and breeders.

So far the genetic resources of underutilized bioenergy crops in general are very poorly documented; little is known about the genetic variability, its useful characteristics, how to access breeding material and share as a public good. Similarly the knowledge about their large scale cultivation for production in different agro ecological and socio economic conditions is still not gathered fully.

2. Objectives

To address these issues, the case study on *Pongamia pinnata* has been carried out with following objectives

- To conduct a detailed genetic resource assessment based on available knowledge through scientific research.
- To develop a broader understanding of the species *Pongamia pinnata* as a source of bio energy and
- To review the existing practical knowledge of its use and potential as bio energy species
- To recommend the further research needs and linking the species to biodiversity conservation and community development.

3. Why *Pongamia pinnata*?

It is now a general understanding and has been glorified at the Johannesburg Summit in 2002 that all development initiatives especially in third world countries have to be sustainable. This is because sustainable development provides long-term solutions with a thorough understanding of social, economic and ecological goals. Development initiatives are sustainable only if long-term economic stability is ensured through benefit sharing, support to rural livelihoods, access to markets, without repercussions on the ecology of an area. Such an approach has to be incorporated into Bio-diesel plantation programmes in order to ensure a long-term solution to the country's energy needs. With respect to the sustainability of bio-diesel cultivation an argument does arise over the two bio-diesel yielding species currently promoted by the Indian Government. *Pongamia pinnata* is a native evergreen tree species, which grows naturally throughout the Indian sub-continent and in some parts of Asia. *Pongamia* or **Karanj** as it is locally called has been traditionally valued for its medicinal properties. Karanj seed cake and leaves are known to have bio-pesticide properties. Such alternative uses provides for the value addition of the resource. Market linkages of Karanj oil have been well established and have only to be strengthened in order to cope with the bio-diesel demand. Karanj is popularly planted as avenue tree and also been planted along farm bunds and near houses for shade. Propagation and cultivation techniques for the species have therefore been well established. On the other hand, *Jatropha* is an exotic weedy species, the mass cultivation of which may have a serious ecological impact. Field trails and yield tests in Chhattisgarh and Punjab have shown disappointing results. The only beneficiaries in the current rage over *Jatropha* plantation have been a few suppliers. Farmers are now reluctant to take up the cultivation of the species as there is a lack of authentic information over yields and market linkages have yet to be established.

Pongamia pinnata (L.), also known as *Millettia pinnata* (L.) Panigrahi, is a fast growing leguminous tree with the potential for high oil seed production and the added benefit of an ability to grow on marginal land. These properties support the suitability of this plant for large scale vegetable oil production needed for a sustainable biodiesel industry.

Pongamia pinnata, however, is a sustainable source of bio-diesel as opposed to *Jatropha curcas*. It is an indigenous tree species and is widely distributed in the country. Karanj is nitrogen fixing tree species and is well suited to a range of ecological conditions and is a suitable species for the restoration of degraded lands. Being a tree species, unlike the shrubby habit of *Jatropha*, *Pongamia* is popularly planted by the Forest Department in India through its reforestation and social forestry programmes. Areas with good natural populations of *Pongamia* provide a great opportunity for the production of bio-diesel on a local scale and will be able to source germplasm for development of the resource.

Section II

State of the art genetic resources, pre breeding & breeding work ...

The commercial cultivation of Pongamia is lucrative .It can make an excellent candidate for bio fuel raw material....

1. Introduction

Pongamia pinnata is a native Indian tree species and the seed oil has been used traditionally. Its importance as a feedstock species for production of bio diesel is a recent development. Once the species is being used as biofuel feedstock, it is necessary to understand it thoroughly, through the existing knowledge of the genetic variability, high yielding capacity of individuals, distribution in various agro ecological zones within its natural range of distribution and selection by breeders as well as by farmers using traditional knowledge. However in case of *Pongamia pinnata* such knowledge is very scanty and there is a need to review the available information as well as scientific literature. In this section we have systematically reviewed the available scientific information about various aspects of plant breeding, genetic variation and selection. The section will form the basis of further checking its potential as bioenergy crop and possibilities of its large scale production.

Genetic variation is an important aspect of biological diversity, since it is the basis of evolution and the adaptation of species to changes in the environment. Variation is also essential for selection and breeding to meet present and future human needs.

The future success of *P. pinnata* as a sustainable source of feedstock for the biofuel industry is reliant on extensive knowledge of the genetics, physiology, and propagation of this legume plant. Review of existing knowledge of this species will provide basis for further research and region wise selection for harnessing its true potential. Being an underutilized species such knowledge is limited and scientists have started doing rigorous research on this species since last decade.

While there is a substantial pool of general descriptive information on *P. pinnata* that can be accessed from the world wide web (<http://www.worldagroforestrycentre.org>; <http://ecoport.org>; [9](http://www.ars-</p></div><div data-bbox=)

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grin.gov; <http://www.winrock.org>), technical reports and selected monographs, there is a considerable gap in the range of detailed scientific publications. If this plant is to become an emerging crop and plantation species grown on extensive tracts of land, then comprehensive studies encompassing the physiology, agronomy, propagation, genetics and molecular biology are needed. In reviewing the available literature, it is clear that *P. pinnata* has a long history of association with indigenous populations; primarily villagers and small landholders (Sekar *et al.*, 1996). What is now required is detailed studies that will provide the knowledge to enable the successful cultivation and management of well-defined elite varieties of *P. pinnata*. However the existing knowledge about the species is summarized in this section.

2. Distribution & Botanical Knowledge

Pongamia pinnata is an arboreal legume that is a member of the subfamily Papilionoideae (of family Fabaceae), more specifically of the *Millettieae* tribe. It is native to a number of countries including India, Malaysia, Indonesia, Taiwan, Bangladesh, Sri Lanka and Myanmar. It has also been naturalized in parts of eastern Africa, northern Australia and USA. This medium-size tree has been successfully introduced to humid tropical regions of the world like New Zealand, and China. Historically, this plant has long been used in India and neighbouring regions as a source of traditional medicines, animal fodder, green manure, timber, fish poison and fuel wood .

Pongamia has a varied habitat distribution and can grow in a wide range of conditions. Typically it is found in coastal areas, along limestone and rock outcrops, along the edges of mangrove forests, tidal streams and rivers. It is hardy and can survive in temperatures from 5 to 50 °C . It can grow at altitudes ranging from 0 to 1200 m in India (GOI 1983).

Due to its deep roots it also has a tolerance for drought and is found in areas with rainfall from 200 to 2500 mm a year. It grows well in both full sun and partial shade and can grow in most soil types. Mature trees can withstand water logging and slight frost.

Pongam is a fast-growing evergreen tree which reaches 40 feet in height and spread, forming a broad, spreading canopy casting moderate shade.

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Up to three-inch-long, pinnately compound, glossy green leaves are briefly deciduous, dropping for just a short period of time in early spring but being quickly replaced by new growth. In summer when all the other deciduous trees are leafless, *Pongam* in India is the most beautiful tree with bright green leaves and cool shade. In spring, *Pongam* is at its finest when the showy, hanging



Pongamia along coast, India

clusters of white, pink, or lavender, pea-like, fragrant blossoms appear; the clusters are up to 10 inches long.

These beautiful blossoms and the glossy, nearly-evergreen leaves help make *Pongam* a favorite for use as shade, or

Wind break. It has also been planted as a street tree, but dropping pods often litter the ground. Pods are elliptical, 3-6 cm long

and 2-3 cm wide, thick walled, and usually contain a single seed. Seeds are 10-20 cm long, oblong and light brown color (Daniel 1997).

Pongamia is locally known as Karanj/ Karanja in India and is distributed throughout India along roadside and railway tracks. It is also known as **Indian beech** tree. It is drought resistant and tolerant to salinity. In India, Karanj has an estimated potential of about 2 lakh MT seeds, which can yield about 0.50 lakh M T oil. It can be propagated by seeds or by stem /root cuttings during July-August. Flowering occurs during April-September depending upon locality. Seed collection period starts from April to June. The seeds contain 27-39% oil that is used for soap making, leather dressing, lubrication, illumination and for medicinal purposes.

Geographic distribution

Native : Bangladesh, India, Myanmar, Nepal, Thailand

Exotic : Australia, China, Egypt, Fiji, Indonesia, Japan, Malaysia, Mauritius, New Zealand, Pakistan, Papua New Guinea, Philippines, Samoa, Seychelles, Solomon Islands, Sri Lanka, Sudan, Tonga, United States of America

3. Genetic Relationship

Leguminosae (Fabaceae) is one of the largest families of flowering plants, comprising over 650 genera and 18,000 species (Polhill, 1981). The family is economically very important being the major source of food and forage and its great diversity (the third largest family in flowering plants) also has attracted much interest in ecological as well as systematic studies. The predominantly tropical tribe Millettieae, consisting of over 40 genera and nearly 1,000 species, is generally thought to have given rise to many temperate herbaceous groups and several tropical tribes of papilionoid legumes, such as Phaseoleae, Indigofereae, Galegeae and their allies (Polhill, 1981; Geesink, 1984) and is considered to be one of the most problematic groups in legume systematics.



Genus *Pongamia* is presented by 30 species (**Refer Annex 1 for list**) and *glabra* (*syn . pinnata*) is most common. Detailed research on nine different species of Papillionadae has been carried out to know the genomic relationships of *Pongamia pinnata*.

Random amplified polymorphic DNA (RAPD) marker was used to establish intergeneric classification and phylogeny of the tribe Millettieae sensu (Geesink 1984) Leguminosae: Papilionoideae and to assess genetic relationship between 9 constituent species belonging to 5 traditionally recognized genera under the tribe. DNA from pooled leaf samples was isolated and RAPD analysis performed using 25 decamer primers. The genetic similarities were derived from the dendrogram constructed by the pooled RAPD data using a similarity index, which supported clear grouping of species under their respective genera, inter- and intra-generic classification and phylogeny and also merger of *Pongamia* with *Millettia* (Acharya et al 2004) .

4. Uses

The Pongam tree is cultivated for two purposes: (1) as an ornamental in gardens and along avenues and roadsides, for its fragrant attractive flowers, and (2) as a host plant for lac insects. It is appreciated as an ornamental throughout coastal India and all of Polynesia. Well-decomposed flowers are used by gardeners as compost for plants requiring rich nutrients. In the Philippines the bark is used for making strings and ropes. The bark also yields a black gum that is used to treat wounds caused by poisonous fish. In wet areas of the tropics the leaves serve as

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green manure and as fodder. The black malodorous roots contain a potent fish-stupefying principle. In primitive areas of Malaysia and India root extracts are applied to abscesses; other plant parts, especially crushed seeds and leaves are regarded as having antiseptic properties.

Botanical Information

Pongamia pinnata (L.) Pierre

Syn.: *Pongamia glabra* Vent. ,*Derris indica* Bennet ,
Milletia pinnata (L) Panigrahi
Family : Fabaceae
Vernacular names : Pongam, Indian beech , Honge

Description

Fast growing, glabrous, deciduous, tree up to 25 m tall, branches drooping; trunk diameter up to 60 cm; bark smooth, gray. Leaves imparipinnate, shiny; young leaves pinkish red, mature leaves glossy, deep green; leaflets 5–9, the terminal leaflet larger than the others; stipels none; stipules caducous. Flowers fragrant, white to pinkish, paired along rachis in axillary, pendent, long racemes or panicles; calyx campanulate or cup-shaped, truncate, short-dentate, lowermost lobe sometimes longer; standard sub orbicular, broad, usually with 2 inflexed, basal ears, thinly silky-haired outside; wings oblique, long, somewhat adherent to the obtuse keel; keel petals coherent at apex; stamens monadelphous, vexillary stamen free at the base but joined with others into a closed tube; ovary sub sessile to short-stalked, pubescent; ovules 2, rarely 3; style filiform, upper half incurved, glabrous; stigma small, terminal. Pod short stalked, oblique-oblong, flat, smooth, thickly leathery to sub woody, indehiscent, 1-seeded; seed thick, reniform (Allen and Allen, 1981).

The seeds contain pongam oil, a bitter, red brown, thick, non-drying, nonedible oil, 27–36% by weight, which is used for tanning leather, soap, as a liniment to treat scabies, herpes, and rheumatism and as an illuminating oil (Burkill, 1966). Also used for lubrication and indigenous medicine. *Pongam* oil showed inhibitory effects on *Bacillus anthracis*, *Bacillus mycoides*, *Bacillus pulilus*, *Escherichia coli*, *Pseudomonas mangiferae*, *Salmonella typhi*, *Sarcina lutea*, *Staphylococcus albus*, *Staphylococcus aureus*, and *Xanthomonas campestris*, but did not inhibit *Shigella* sp. (Chaurasia and Jain, 1978). The oil has a high content of triglycerides, and its disagreeable taste and odor are due to bitter flavonoid constituents, Pongamiin and Karanjin. The wood is yellowish white, coarse, hard, and beautifully grained, but is not durable. Use of the wood is limited to

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cabinetmaking, cart wheels, posts, and fuel (Allen and Allen, 1981). Both the oil and residues are toxic. Still the press cake is described as a "useful poultry feed." Seeds are used to poison fish. Still it is recommended as a shade tree for pastures and windbreak for tea. The leaves are said to be a valuable lactagogue fodder, especially in arid regions. It is sometimes intercropped with pasture, the pasture grasses said to grow well in its shade (NAS, 1980a). Dried *Pongam* leaves are used in stored grains to repel insects. Leaves often plowed green manure, thought to reduce nematode infestations. Its spreading roots make it valuable for checking erosion and stabilizing dunes. Twigs are used as a chew stick for cleaning the teeth. The ash of the wood is used in dyeing.

According to Duke 1983 *Pongamia pinnata* has been reported from the Hindustani Center of Diversity. It tolerates drought, frost, heat, limestone, salinity, sand, and shade. ($2n = 22$).

5. Resource Assessment of *Pongamia pinnata*

Since *Pongam* tree is native to India and is distributed throughout the country except in higher Himalayan reaches, far west and eastern Himalayan region of the north eastern states, there is a huge untapped potential of these trees as bio energy species. Due to its natural distribution it has many advantages over other exotic oil yielding species. They include

1. The oil is non edible
2. Oil is in use in the country for many centuries
3. The oil percentage is high up to 40%

Resource assessments are extremely important for naturally growing trees when we try to commercialize the new underutilized species. For cultivation and yield in case of trees it takes anywhere between 5 to 20 years for maturity depending up on the species. Resource assessments are important for identifying high yielding individuals and selecting the correct agro climatic zones for the large scale cultivation.

However there are no specific studies available that talk about the assessment of existing individuals and populations of the tree within the country. One such exercise has been carried out by Applied Environmental Research Foundation (AERF) in India using the elaborate resource assessment strategy based on methodology developed by FAO. The summary of the work of AERF for resource assessment of *Pongamia pinnata* has been provided here, as it will help setting an example for all potential underutilized species that are being studied across the globe as potential energy sources especially wild non edible oil trees.

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A Resource Assessment or a Quantitative Inventory of a resource, as per the FAO can be defined as:

“A biometrically rigorous enumeration of the abundance and distribution of resource populations”

The need for such an assessment may arise as a result of an increase in demand for a particular resource or for the purpose of developing resource based enterprises as well as to understand demand and supply linked to a resource. In any of these cases, an understanding of the abundance and distribution of the resource will further determine how the resource will be used, exploited and managed. A resource or resource population in this case is a tree species or a group of species that provide a product that is commercially or traditionally important in raw or processed form. Depending on its objective and implications, a resource assessment may be conducted at various scales. In the case of promoting and developing NTFP based enterprises, Wong et al (2001) conducted village-based assessment whereas for developing nation wide policy and incentive schemes or for commercialization of a resource, Wong (1999) proposed a national or regional strategy for the assessment. In general, resource assessments are useful for:

- Understanding potential of a resource for future supply, commercialization of a resource or for development of resource based enterprise
- Understanding resource demand and supply and to determine sustainable harvest levels

A Resource Assessment is therefore a vital tool in the planning, management and development of a resource or a resource pool.

5.1 The need for Resource Assessments for Large-scale Utilization of Biofuel Species

A resource assessment forms a scientific base for the management and development of a resource, although what needs to be discussed here is how resource assessments can provide viable information for the planning and implementation of large-scale cultivation programmes such as those for bio-diesel. Nation-wide resource development projects have failed in India , due to the lack of a feasible plan supported by an assessment of the current status of the resource and how it can be developed. Resource Assessment forms the first step towards the Resource Development process, which is further illustrated here.

5.2 The Resource Assessment of *Pongamia pinnata* in Maharashtra , India

There are many oil-seed bearing plants in India suitable for bio-diesel production. Although In India, in terms of production on a national scale *Pongamia pinnata* and *Jatropha curcas* proved to be promising resource species. *Jatropha* has been extensively planted in the African continent and in some countries in South America and Asia. A considerable amount of studies have been undertaken for the species, however there is a need to have a feasibility study of the *Pongamia pinnata* for the Indian sub-continent to plan for the sustainable utilization and resource development of this underutilized species.

Pongamia being a native species of the region, relevant studies of the species with respect to its potential for large-scale cultivation are not available. The need was therefore felt for a comprehensive Resource Assessment of *Pongamia pinnata* following the Indian Government's decision to promote the species for bio-diesel production.

Applied environmental Research Foundation (AERF) had conducted a Resource Assessment of *Pongamia pinnata* in Maharashtra state in India with a view to promote the species in the state.

The primary objectives of the assessment were

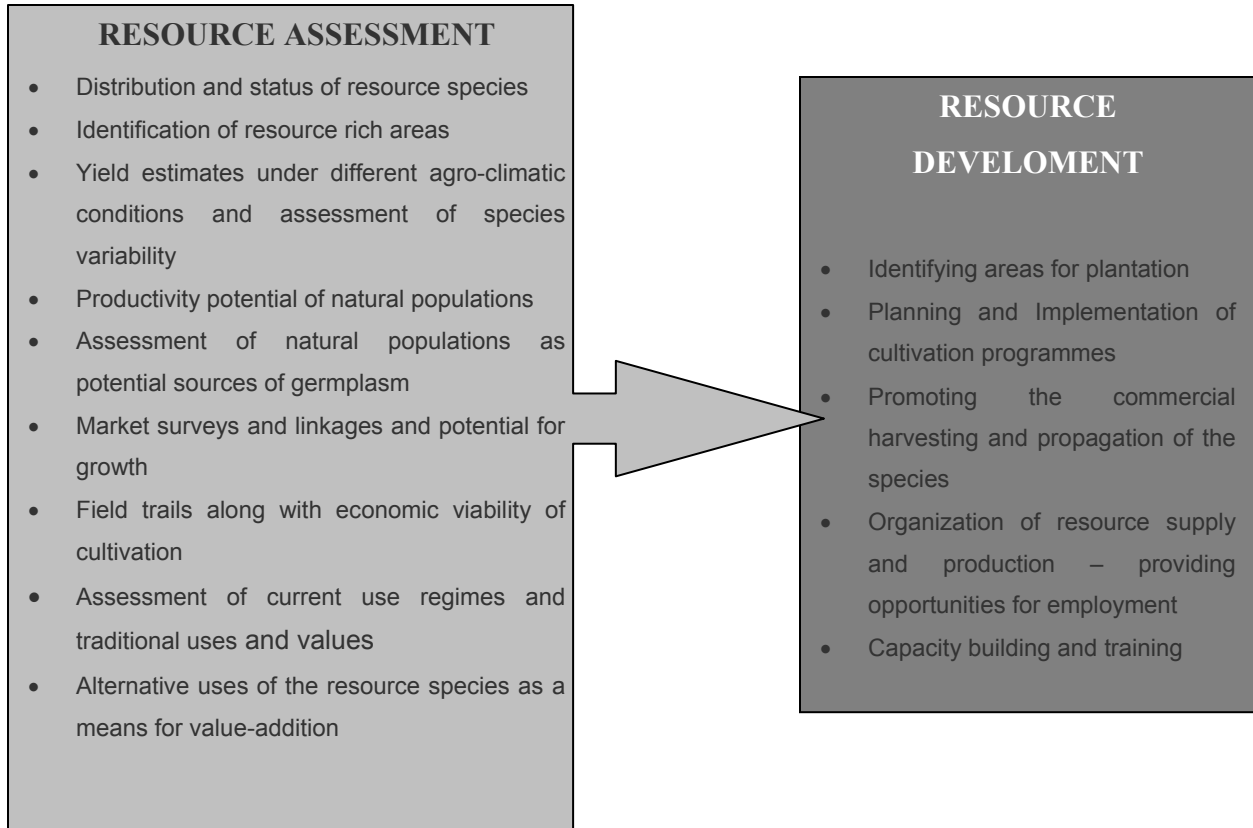
- To assess the current status and productivity of the resource species (*Pongamia pinnata*) in Maharashtra
- To conduct yield estimates with respect to area and size variations
- To conduct field trails of the species and assess potential of the species for large-scale cultivation

AERF has conducted a detailed resource assessment of *Pongamia pinnata* in two districts of Raigad & Solapur, from the state of Maharashtra in India. The detailed report of the assessment is available at www.aerfindia.org The conclusion and relevance of RA for this study is provided below .

5.3 Methodology of Resource Assessment

A Resource Assessment is a quantitative study of an identified resource within an area. Being a study with numerical results, a resource assessment requires considerable biometric rigor in order to arrive at a valid conclusion. An ideal assessment includes a study of the distribution of the resource species, its extent and status of the population within an area of interest.

Fig I Resource Assessment & Development



Resource Assessment methodologies draw on from various techniques and methodologies from the ecological and social sciences. Field methodologies differ according to the objectives of the study and the resource in question. Assessment periods may range from one-time surveys to long-term studies depending upon the objectives of the studies and the resource/s of interest. Resource Assessments broadly incorporate methods from the ecological, economic and social sciences.

Table I

Resource Assessment objectives	Techniques incorporated from	Brief note on methodologies
To assess the current status of the resource	Ecology/Forestry	Population and distribution studies, quantitative inventories
To assess the value of the resource	Economics	Market surveys, evaluation of a resource for commercialization, cost-benefit studies
To assess the cultural/social value of a resource	Social Sciences	Ethnobotany inventories, Participatory Rural Appraisal (PRA)

5.4 Results & Discussions

Resource assessment is a tool to understand the potential of existing resource. In case of underutilized species like *Pongam* it proved extremely important as AERF could build the *Pongam* based village level decentralized bio fuel enterprise. Details of this are provided further in section III of this case study. For any underutilized species and its promotion for use at large scale the propagation, plantation and cultivation are given importance. In case of trees the gestation period, may be more and actual potential may not be harnessed through cultivation. Such approach of cultivation is good for species that are not readily available. Whereas in case of species like *Pongam*, that are common and being used merely as fuel wood it is important to assess the existing potential. If such species are brought to the use, it immediately arrests its felling and cutting for fuel wood and addresses the issue of conservation of local biodiversity (Sarnaik & Godbole 2008) . *Pongam* is common all over India and such resource assessments at regional level are recommended.

Resource Assessment studies are useful for

- Strategic Planning for the promotion of Resource based industries.
- Determine Resource status and distribution to plan development
- Planning for investment or development of a sector
- Integrating resource commercialisation with rural development
- Determine policy especially regarding financial incentives
- Understanding the potential of existing resource base for large scale production.

(modified from FAO 1999)

6 .Ethnobotany of *Pongamia pinnata*

Promotion of the species for commercial production is based on the knowledge of its use. Ethnobotanical studies of *Pongamia pinnata* revealed 2 categories of results viz. traditional uses of the species and traditional knowledge linked to the species (Punde , Godbole & Raskar et al 2007) . These findings further supported the theory that local people will be more likely to take up cultivation of a species traditionally valued by them as opposed to the introduction of new species. The results of the investigation of traditional uses and traditional ecological knowledge have been provided here.

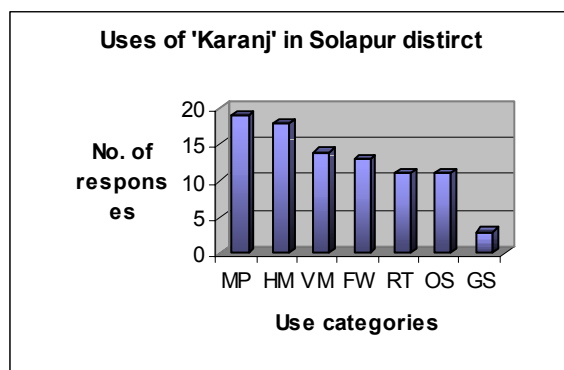
6.1 Traditional Uses

As a part of AERF's RA study , over 50 respondents were interviewed and an additional 30 questionnaires filled throughout Solapur district . Uses documented were classified into 7 categories viz.

- i) use of leaves and seed oil cake for manure and organic pesticide
- ii) use of oil for medicinal purposes
- iii) use of oil as ethno-veterinary medicine
- iv) fuel wood
- v) use for religious purposes
- vi) plantation of 'Karanj' for ornamental and shading purposes
- vii) other general uses

The number of responses for each category has been shown in the following representation in order to illustrate the most common uses (Punde, Godbole & Raskar 2006) .

Fig II



MP=Manure & Pesticides, HM=Medicinal uses, VM=ethno-veterinary uses, FW=fuel wood, RT=religious uses, OS=ornamental and shading purposes, GS=general uses

6.2 Traditional Ecological Knowledge

The relevance of documenting local people's knowledge regarding the ecology of the species lies in understanding the awareness of the people with reference to the species under study. The ethnobotanical studies described here involved documenting local people's knowledge of *Pongamia pinnata*.

6.3 Traditional Uses and Importance of the Species

The results (see Fig II) revealed that 'Karanj' is most commonly valued for its manure and pesticidal properties. The leaves and more commonly the seed oil cake are used. In recent times, the seed oil cake is being marketed and popularly sold as an organic pesticide. Traditionally, the use of *Pongamia* leaves in the storage of grains is widespread throughout Maharashtra (Kulkarni & Kumbhojkar 1996). *Pongamia* is commonly used for its medicinal properties both for human ailments and wounds on cattle. Respondents in the study site mainly referred to the use of seed oil as apposed to other plant parts. Mentions of traditional use of oil is extensive in a number of publications including the use of oil for skin diseases in Ethnobotanical surveys of Thane and Baramati districts of Maharashtra (M. J. Kothari & K. M. Rao 1999; S.S. Deokule & D.K. Magdum 1992). The seed oil was mainly used for external application if rarely consumed in minute quantities to induce vomiting. The other most popular use of the seed oil was its application on cattle wounds and to repel flies. Again, the use of stem bark decoction in ethno-veterinary practices mentioned by K. N. Reddy and R. R. Venkata Raju (1999) and by N. R. Rama Rao et al (1999) in their investigations in Andhra Pradesh as well as other ethno-veterinary investigation in other parts of India (D.C. Pal 1992) and H. Prakash Pandey, B. K. Verma & S. Narain (1999) were not documented in Maharashtra. Another distinction between the observed and published literature was that 'Karanj' plant parts and seed oil was noted to have been used as an ingredient in medicinal pastes and decoctions whereas the observations made in this research reveal that 'Karanj' oil and its plant parts were only used in isolation for curing ailments. Therefore, in general the ethnobotanical knowledge linked to *Pongamia pinnata* does not seem to be as extensive as compared to published literature reviewed here. This may lend itself to the fact that Solapur as a district is relatively developed through its extensive irrigation systems and cash crop agriculture whereas the literature reviewed here has been focused on tribal communities. Based on this distinction, assumptions of the study area can be made whereby ethnobotanical knowledge of tribal and rural communities is distinct or indigenous knowledge in the region has depleted due to modernization and development characterized by the advent of market economy and cash crop agriculture.

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However, based on this research and the literature reviewed, the use of seed oil for skin diseases and the use of seed oil cake as manure is common throughout India.

In the district of Solapur, where tree cover is sparse and the demand for energy requirements are high, the lopping of *Pongamia* trees for firewood is common throughout the district. It is a preferred fuel wood species due to its easy availability, fast growth and its ability to coppice well.

Religious importance of the species was also documented, primarily being the use of leaves in garlands, during religious and marriage processions. 'Karanj' is also popularly planted near houses throughout the district for its cool shade although the myth of *Pongamia* as being a bad omen if planting near houses, as mentioned in the 'Surpalkrut Vruksha-ayurvedh' -chapter 1, verse 30 (Nene & Sadhale 2006) does not seem to be part of the local knowledge here. Other uses classified here in the general category include the use of *Pongamia* wood for making charcoal, shoots for basket making and most importantly, the use of oil in traditional oil lamps. The use of oil for lamps was said to be widespread before the advent of electricity.

It is therefore fair to claim that local people value *Pongamia* for a number of purposes, mostly for its medicinal and pesticidal properties. In some of the surveyed villages, *Pongamia* seeds were commonly collected and sold locally. Due to the existence of markets and traditional value linked to the species, local people were found to be more willing to partake in the commercialization of the species for bio-diesel production. Over 65% of the respondents were willing to take up cultivation of 'Karanj' for bio-diesel. This proves to be a promising figure for large-scale cultivation schemes and development programmes.

7. Genetic Variability in *Pongamia pinnata*

The knowledge of genetic variability and association between pod and seed traits is considered to provide considerable help in genetic improvement of the species.

The study of pod and seed characters with oil content of the natural populations is often considered to be useful step in the study of the genetic variability. Therefore, some of the basic material (seed) from the trees having more seed weight and oil content may be used for further improvement programme, since the improvement in germination and seedling growth through seed size manipulation has been reported in case of *Hardwickia binata* (Ponnammal et al. 1993) and *Jatropha curcas* (Kaushik et al. 2003).

A study has been conducted on Forty Candidate Plus Trees (CPTs) based on the morphometric and qualitative traits from different locations of Haryana state

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of India (Kaushik et al 2007). It is clear from the study that considerable genetic differences existed in pod– seed morphological characters and oil content among various seed sources of *Pongamia pinnata*. CPTs 18, 20, 33, 13 and 29 were found to be the best on the basis of oil content and pod–seed characters, which revealed promise in their further exploitation for plantation and selection for improvement. High genotypic correlation coefficient between pod and seed characters revealed that the traits are genetically controlled and selection can be very effective in tree improvement programmes of these species.

The analysis of variance indicated that there was significant variation among the forty candidate plus trees for all pod and seed characters studied (**Table 2**).

Seed length had a positive and highly significant association with seed breadth, seed thickness, 100-seed weight and 100-pod weight while it showed positive and significant correlation with pod-seed ratio and oil content at both genotypic and phenotypic levels .

Maximum pod length (57.03 mm) was observed in CPT-18 and minimum (37.53 mm) in CPT-1. Pod thickness also varied significantly among all the CPTs. 100-pod weight varied from 122.40 g in CPT-38 to 403.93 g in CPT-33. Maximum value for seed length (24.16 mm) was observed in CPT-33. Maximum 100-seed weight (186.80 g) was recorded in the seeds collected from CPT-33. The pod–seed ratio varied from 0.33 to 1.45.

Table 2 Analysis of variance for pod and seed traits in *Pongamia pinnata*

Source	Length (mm)	Breadth (mm)	Thickness (mm)	100-pod weight (g)	Length (mm)	Breadth (mm)	Thickness (mm)	100-seed weight (g)	Pod–Seed ratio	Oil content (%)
Replicate	2.673	0.638	0.036	312.494	5.404	1.966	0.193	40.0	0.097586	179.776
CPTs	57.131	15.946	3.301	11627.589	11.723	5.297	2.577	2534.686	0.252524	20.927
Error	1.183	0.314	0.156	84.482	0.986	0.178	0.159	0	0.000742	0

(Source : Kaushik et al 2007)

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Variation within *Pongamia* seeds from Coastal and Arid Zones of Maharashtra India
(Source : AERF *Pongamia* Report 2007)

According to Kaushik et al 2007, high genotypic correlation coefficient between pod and seed characters revealed that the traits are genetically controlled and selection can be very effective in tree improvement programmes of *Pongamia pinnata*. The study clearly indicates that considerable genetic differences existed in pod–seed morphological characters and oil content among various seed sources of *Pongamia pinnata*.

The ovaries of *P. pinnata* mostly contained two ovules (95.04% of the flowers) and occasionally three (4.96%), with a mean of 2.05 ± 0.22 ovules per ovary (N = 121). A majority of the pods (90%) had only one seed (1.10 ± 0.42 ; N = 267). In *Pongamia pinnata* only one of the two ovules develops into a seed in most of the pods. Since pollen was not found to be limiting and reduced fertilization could not completely explain the observed frequency of seed abortion, it implied an effect of post fertilization factors.



Pongamia pinnata (VNK-P 113),
Unique accession with high seeds/pod from
Vizianagaram district, Andhra Pradesh
(Source : DARE/ICAR Annual Report 2007-2008)



Pongamia pod with two seeds
AERF Collection from Coastal
Maharashtra.

The experiments carried out in Bangalore Botanic Gardens (arathi et al 1999) showed that Aqueous extracts of developing seeds and maternal tissue (placenta) did not influence abortion in vitro, suggesting that abortion may not be mediated by a chemical. Experimental uptake of ¹⁴C sucrose in vitro indicated that both the stigmatic and the peduncular seed have similar inherent capacities of drawing resources, but the peduncular seed is deprived of resources in the presence of the stigmatic seed. This deprivation of the peduncular seed could be offset by supplying an excess of hormones leading to the subsequent formation of two seeds in a pod. The prevalence of single-seeded pods in *P. pinnata* seem therefore to be a result of competition between the two seeds for maternal resources.

8. Variability Assessment for Biofuel Production

With the growing interest in the seed oil of *Pongamia pinnata*, the need for raising plantations has been realized. In this context, the present study was undertaken to assess the existence of variability for some of the important biodiesel parameters as a prelude to selection of more efficient biodiesel yielders. With this objective the survey, collection and characterization of *Pongamia pinnata* has been undertaken to assess the variability existing for various economically important parameters for its development as a profitable crop for biodiesel production.

Wide variability in oil content was observed in 75 germplasm accessions of *Pongamia pinnata* (L.) Pierre collected from Telengana region of Andhra Pradesh, India. Out of these, fatty acid profiles of 21 accessions with varying seed oil content were examined. Large variation was observed in stearic, oleic and linoleic fatty acid composition i.e. 1.83–11.50%, 46.66–65.35% and 12.02–32.58% respectively while less variation i.e. 9.25–12.87% was found with palmitic acid content. Saponification number (SN), iodine value (IV) and cetane number (CN) of fatty acid methyl esters of oils varied from 183.3 to 200.91, 74.78 to 100.98 and 50.85 to 59.11 respectively (Mukths, Murthy & Sirpal 2008) .

The selection criteria for promising material for large scale plantations includes high seed yield coupled with high oil content. In addition to these parameters, the oil quality aspect should receive due attention with more efficient values for biodiesel standards adding to the overall efficacy of the biofuels. Though oil quantity and quality are greatly affected by environment and the material evaluated is heterogenous, significant variability has been recorded for most of the traits evaluated which can be utilized for selection of elite material in future.



Pongamia pinnata plantations are gaining importance due to the less crop husbandary management practices required in comparison to *Jatropha*. Selection of appropriate genotypes which take into account the biodiesel standards viz. high cetane number besides high seed yield and oil content will result in more efficient biofuel types leading to accrual of higher benefits when such large scale plantations are considered. The establishment of plantations of promising genotypes through clonal means can also result in increased productivity. In the present investigation, genotypes DORPP 49, 72 and 83 were most efficient biodiesel types identified for further utilization and development.

9. Seed & Seedling Traits ..

In India, *Pongamia pinnata* seeds ripen from February to May. Pod production starts 5-7 years after sowing. They do not open naturally, and must decay before seeds can germinate. In Florida, it sheds its leaves in April and develops new leaves and flowers from May onwards.

Quality seed has been recognized as an important input in forestry and is considered essential for increasing production. Seed polymorphism has been found to play great role in seed germination, survival and seedling growth (Pathak et al., 1980). Source variation tests are necessary to screen the naturally available genetic variation to select the best planting material for higher productivity (Bhat and Chauhan, 2002).

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In this study Bhat & Chauhan (2002) made an effort to evaluate the extent of variation among the seed sources with respect to different seed and seedling traits. An experiment was conducted during 2005-06 at Department of Agro-forestry, College of Forestry, Sirsi India. The seeds of *Pongamia* were collected from eight different locations falling under tropical climates. Initially, seeds were measured for seed length, width and 100 seed weight. The seeds were sown in polybags in a randomized block design. Daily germination was recorded and seed sources were assessed for germination per cent and observations were also recorded on growth parameters like seedling height, collar diameter, number of nodes and number of leaves per seedling.

There was significant difference among seed sources for seed and seedling traits. Seed length amongst the different sources used varied from 7.70 to 11.13 mm and seed width from 6.95 to 9.22 mm. The 100 seed weight varied from 19.80 to 32.20 g. It is evident from the experiment that, seed with higher weights, possessed higher seed length and width. Results revealed wide range of variation in germination per cent (69.61 to 89.20). Heavier seeds possessed higher germination per cent than that of smaller and lighter seeds, may be because of more stored food in endosperm (Shivanna, Bhalchandra & Suresh 2007). For large scale propagation and seed selection it is important to have similar regional studies.

10. Germination & Seed Storage Behavior

It is predominantly cultivated through seeds and the genetic diversity has been conserved through storage of seeds, the most common conventional and economical method. However, the seeds of *Pongamia pinnata* suffer from germination and storage problems. Seed storability varies greatly among tree species and is mainly influenced by the variation in climatic conditions, such as temperature, rainfall and relative humidity, which fluctuate in India and other south Asian countries across the year.

This makes the storage of seeds difficult for commercial exploitation and cultivation. Differences in storage behaviour are often associated with morphological, physiological, anatomical, structural and biochemical composition of the seeds, which affect the desiccation and chilling sensitivity of seeds and thereby the longevity in storage.

In a study, conducted by Santosh Kumar et al. (2007) in India, higher seed moisture content (40–60%), large seed size and weight have often been found associated with recalcitrant storage behaviour of seeds (weight of 1000 seeds exceeding 500 g). However, *Pongamia*, despite having tropical/subtropical habitat and large and heavy seeds with moisture content of about 14% on fresh-weight basis, is not sensitive to desiccation and chilling. Therefore it can be

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stored normally with drying of seeds to 5–10% moisture level under low temperature conditions.

A survey on the symptom and severity of the leaf spot disease of *Pongamia pinnata* was conducted in the nurseries of the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU), Bangladesh Forest Research Institute (BFRI) and Aronnak Nursery in Chittagong. The highest infection percentage and disease index were found in IFESCU nursery, followed by BFRI and the lowest was recorded in Aronnak nursery. The associated organism of leaf spot disease of *Pongamia pinnata* was isolated from the diseased plant parts and the pathogenicity was established with the isolated fungus. *Colletorichum gloeosporioides* Penz, was proved to be pathogenic (Mridha et al 2007) .

The successful introduction and subsequent expansion of plantings of any new crop species is reliant on the ability to develop simple and reliable methods for the propagation of large numbers of plants. Further, the long-term viability of tree crop species such as *P.pinnata* is dependent on good pruning management practices. In addressing this second issue, coppicing and pollarding have been reported as successful means of agroforestry management practices for *P. pinnata* (Misra and Singh, 1989). With respect to mass propagation, *P. pinnata* can be propagated easily from seed (Handa et al. 2005; Singh et al., 2005). To this, Manonmani et al. (1996) found that there was a direct relationship with seed size and germination efficiency, but only with fresh seeds. Germination and plant vigour began to decrease following storage of seeds for three months or more.

Despite the successes seen in germination trials, in the context of the development and continued vegetative propagation of superior genotypes, other protocols are required. Palanisamy et al. (1998) reported the development of adventitious roots in shoot cuttings from *P. pinnata*. The formation of adventitious roots was most prominent in association with the development of new shoots on the planted cuttings. Further, the three auxins, indole acetic acid (IAA), indole butyric acid (IBA) and naphthyl acetic acid (NAA), promoted adventitious root formation, with IBA the most effective inducer. Karoshi and Hegde (2002) also undertook a study examining the propagation of stem cuttings, and looked at the potential of softwood grafting.

Similarly to Palanisamy (1998), IBA (at 2500 ppm) was found to promote rooting of *P. pinnata* and in addition the grafting was very successful at 95%. In a third study, Ansari et al. (2004) examined the effect of dipping semi-hardwood coppice shoot cuttings in KMnO₄, KCl, KHPO₄, KH₂PO₄ or K₂SO₄ on both IAA ionization and adventitious rhizogenesis. At an equimolar K concentration of 5 mM, the S and P salts had a significantly positive effect on the percentage of cuttings that produced new sprouts and roots, the number of roots per cutting and the root length, while at the same time reducing the amount IAA ionization. In contrast,

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the Mn salt decreased adventitious rhizogenesis, while the chloride salt had no effect.

Finally, Srinivas and Rao (2006), at a recent meeting of the Society for In Vitro Biology, reported on what they claim to be an efficient and reproducible system for the regeneration of *P. pinnata* from immature embryo derived cotyledonary explants.

In vitro plant regeneration protocol, has been developed for *P. pinnata* using cotyledonary nodes from axenic seedlings (Suglaet al2007) . The regeneration system can be adapted for mass propagation due to readily available mature seed embryos. Furthermore, such a plant regeneration system may offer a starting point for the development of genetic transformation technologies in this species.

The results of the another set of experiments with mature-tree-derived Pongamia meristematic buds indicate that BA, KN, and Z are ineffective in inducing multiple shoots, and TDZ in equimolar concentration influences the meristem differently. At the tested concentrations of TDZ, sprouting of the axillary buds is suppressed and meristematic domes are formed. (Sujatha & Hazra 2007) .

Natural reproduction is profuse by seed and common by root suckers. Direct sowing is common and most successful. Seeds require no pre-treatment and germinate within 7 days to 1 month of sowing. Germination is hypogeal and the radical develops quickly before the plumule emerges. In the nursery, it can be planted at a close spacing, as young plants tolerate shade well. In India a spacing of 7.5 x 15 cm is recommended. Seedlings attain a height of 25-30 cm in their first growing season. Transplanting to the field should occur at the beginning of the next rainy season when seedlings are about 60 cm in height. Seedlings have large root systems and soil should be retained around the roots during transplanting. Pongam can be propagated by stump cuttings of 1-2 cm root-collar diameter. Propagation by branch cuttings and root suckers is also possible.

11. Pongamia Cultivation

Pongamia grows very well along water ways. Its propagation is by direct seedlings or by planting nursery raised seedlings. Propagation by branch cuttings and root suckers is also possible .Its seeds can immediately be sown after removing from matured pods and start germination after 7 days of sowing and cent percent seeds germinate. Seeds may be stored for an year without removing from pods and when removed they may be stored in an airtight box for delayed sowing. Fruits setting of Pongamia starts from fifth year onwards of plantation. It flowers in April-May and fruits mature in January-February. Each pod bears single seed and average fresh weight of a matured seed is 1.2 gm.

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From 5th year onward of plantation it starts flowering and fruiting. Commercial productions of seeds start from 10 years onwards of plantation and a full-grown tree may yields up to 100 kg. or even more fresh seeds per annum up to 60-70 years. In North East India cattle do not browse Pongamia though in other parts of the country its leaves are used as fodder. It is very easy to grow and needs little care.

Tap roots of Pongamia are deep seated and mines water for its need even from 10 meters depth without competing other crops. It is also a drought resistant plant. Oil cakes are good organic fertilizer and bears nitrogen 4%, phosphorous 1% and potassium 1% ((Kaushik and Kumar, 2004) which is better than vermi compost . Root nodules formation due to Rhizobium strains in nursery and in fields is common by which nitrogen is replenished in soil. The cost of cultivation is comparatively low (Gogoi 2006) and the yields are estimated at Indian conditions as INR 16000 (USD 310) /ha (400trees).

11.1 Propagation Methods

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11.2 Tree Management

Seedling survival and growth benefit from annual weed control for the first 3 years after transplanting. Growth of young trees is fairly slow; a growth of 1.3 m in height and 0.4 cm in diameter in 13 months was recorded in India. Trees coppice well and can also be pollarded. When planted as a shade or ornamental tree, pruning may be necessary to obtain a trunk of appropriate height. The spacing adopted in avenue planting is about 8 m between plants. In block plantings, the spacing can range from 2 x 2 m to 5 x 5 m. The lateral spread of roots on this species, about 9 m in 18 years, is greater than most other species; moreover it produces root suckers profusely.

Because of these characteristics, Pongam is unsuitable for agroforestry and has the potential to become a weed if not managed carefully. Individual trees yield 9-90 kg of pods annually, while mature trees yield 8-24 kg of seeds annually. In meeting the future demands for biodiesel it will be important to establish extensive plantations comprising elite varieties of trees. This challenging task will require tools in the fields of genetics, molecular biology, plant propagation and agronomy that will enable this now important legume to be fully characterized, and for optimal yields of oil to be achieved.

11.3 Diseases

Disease is a regular phenomenon in the nursery seedlings and most affected are the young plants. Information about different diseases of *P. pinnata* appears very limited. Leaf spot diseases recorded mainly involve *Ganoderma lucidum* causing root rot, *Fomes merillii* attacking base of living trees, *Ravelia hobsoni* attacking lower leaf surface and producing chestnut brown teliospore heads with yellowish brown, and also include simple appendages, *R.stictica* and *Microstroma pongamiae* causing leaf coloured spots from white to cream and giving a yellowish appearance to the infected leaves, *Cercospora pongamiae* and *Sphaceloma pongamiae* causing anthracnose spots on leaves, tender shoots and pods resulting in severe damage and early defoliation in young seedlings and trees (Munjaj et al. 1959; Butler and Bisby 1960; Bakshi and Singh 1967; Browne 1968; Kar and Mandal 1969; Wani and Thirumalchar 1970).

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A survey on the symptom and severity of the leaf spot disease of *Pongamia pinnata* L. was conducted in the nurseries of the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU), Bangladesh

Forest Research Institute (BFRI) and Aronnak Nursery in Chittagong. The highest infection percentage and disease index were found in IFESCU nursery, followed by BFRI and the lowest was recorded in Aronnak nursery. The associated organism of leaf spot disease of *P. pinnata* was isolated from the diseased plant parts and the pathogenicity was established with the isolated fungus (Mirdha et al 2007). *Colletorichum gloeosporioides* Penz was proved to be pathogenic. The inhibition of mycelial growth of *C. gloeosporioides* was observed and identified as suitable fungicides (Bavistin, Cupravite and Dithane M-45) and doses (0.05, 0.10, 0.50, 1.00, 1.50 and 2.00).

The lowest and highest mycelial growth were respectively found on Bavistin and on Cupravite, at the concentration of 0.05 after 8th day of incubation. It indicates that out of the three tested fungicides, Bavistin showed most effective, followed by Diathane M-45, and Cupravite was ineffective for its very little inhibition on mycelial growth.

In case of *Pongamia pinnata*, very limited studies have been conducted so far to know the other pests and diseases. There is a need to conduct research before taking up large scale plantations.

Section III

Potential as Bio energy source and limitations

Biofuels will likely be part of a portfolio of solutions to high energy prices, including conservation, more efficient energy use, and use of other alternative fuels.

.....*William Coyle*

1. Introduction

Rudolf Diesel in 1895 ran his first exhibition engine on a SVO -- peanut oil! It was a story of the past. However due to shortage of the fossil fuels , increasing demand of the energy and ever increasing technology; dependent on the fossil fuels being used for human well being; it is now important to look at the alternatives to these fossil fuels and to look at the renewable sources of energy. This urgent need then attracted the attention of researchers and policy makers again to the SVOs which Rudolf Diesel used to run the engine. However we can not afford to use peanut oil for production biofuel. Many developed nations like USA and European Union use the SVOs of Soybean, Maize and Sunflower for production of the biofuel. It is already a debate all over the world to use the food crops for biofuel. Such luxuries however are not affordable to developing countries where food security is far more important issue. Feeding the hungry populations is the priority than to use food crops for bio fuel production.

The world has been facing the problem of continuous supply of fossil fuels and the increasing demand of these fuels by rapidly globalizing countries like China. At the same time there has been an increased awareness about the global warming and climate change within this decade. With this new understanding; the geographical limits become irrelevant from the environmental perspective as all the nations will have the impacts of this universal phenomenon. In such a situation there are many efforts initiated to use the potential of non edible oil producing plants for production of biofuel.

Biofuels are currently viewed with some skepticism around the world. Not only has demand for plant-based fuels played a role in food-price inflation; some countries are clearing precious rainforest to make space for new plantations. What is often overlooked is that biofuels can serve both climate and agricultural-development purposes.

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Worldwide, oilseed crops occupy an area of 166.36 million hectares with a production of 295.6 million tones and productivity of 1777 kg/ha (FAO, 2003). In India, a developing nation, area under oilseeds is 23.7 million hectares with a production of about 25 million tones and a productivity of just about one ton/hectare. The oilseed production in the country presently meets only 60-70% of its total edible oil requirements and the rest is met through imports (Rajvanshi et.al 2007) Therefore it is not possible for developing countries to consider the edible oil yielding crops as potential SVO candidates for production of biofuels. In the countries with high biodiversity (Coinciding with the developing nations) large number of wild species, has potential of production of SVOs for biofuels. *Pongamia pinnata* is one such species and its potential is discussed in details here. Before discussing *Pongamia pinnata*, it is important to understand the bio fuels/biodiesel, scenario of production, at global as well as regional and local level.

2. Biodiesel

Biodiesel is a renewable fuel produced from agricultural resources such as vegetable oils. In the United States, most biodiesel is made from soybean oil; however canola oil, sunflower oil, recycled cooking oils, and animal fats are also used. However since there is a huge debate on use of food oils for production of bio fuels , within last five years more and more attention is diverted to wild non edible species for production of biofuels. The front runners are *Jatropha curcas* and *Pongamia pinnata*. In the developing countries especially tropical countries, large numbers of wild species have the potential of oil production. These underutilized species like *Calophyllum inophyllum*, *Schelshlera olosa* , *Actinoidaphne angustifolia* and *Madhuca latifolia* are important and need research. Even in the case of front runners like *Jatropha* and *Pongamia*, however the complete scientific understanding of the species is still very poor. In case of other species the use as SVOs is a recent understanding.

2.1 Biofuels Worldwide

While fossil fuels still account for more than 95 percent of the global transportation fuel market, biofuel production is growing roughly 15 percent per year, a rate over ten times that of oil. Under mounting pressure to improve domestic energy security and combat global climate change, countries are now turning to ethanol and biodiesel to meet rising transportation fuel demands. In 2005, the U.S. pledged to nearly double ethanol production by 2012, and the European Community recently announced that biofuels will meet 10 percent of their transportation fuel needs by 2020.

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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. (Parisara 2005)

2.2 Status of Biofuel Production in India

India consumes more than 250 million tones of fossil fuels every year. This comprises of approximately 40 million tones of diesel. India is ranked fifth in the world after China, Japan, Russia and the U.S. in terms of fossil fuel consumption. Recently in India the Planning Commission, Government of India launched "National Mission on Biodiesel" with a view to find a cheap and renewable liquid fuel based on vegetable oils (Shukla, 2005). The rural development ministry has been appointed as the nodal ministry for implementing the programme. This mission is being carried out in two phases – the first phase involving a demonstration stage for plantation of Jatropha on four lakh hectares and associated research activities for establishing the commercial viability of the fuel, and phase two for carrying out a self-sustaining expansion of the biodiesel programme.

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.

(Source : Parisara 2005)

[To make biodiesel, the base oil is put through a process called "esterification." This refining method uses an industrial alcohol (ethanol or methanol) and a catalyst (substance that enables a chemical reaction) to convert the oil into a fatty-acid methyl-ester fuel (biodiesel).]

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Biodiesel production in India has reached a decisive stage and the country is about to make a beginning by introducing a five percent blend of biodiesel with conventional diesel at selected districts in different states (Behl, 2006). In order to attract and secure private participation on larger scale, Government of India has fixed the procurement price of biodiesel as Rs. 25/liter with a provision to revise it later. Some biodiesel units using TBO and imported palm oil, have already started manufacturing biodiesel on small scale.

Though India is the fourth largest producer of edible oilseeds in the world, it produces only 60% of its total oilseed requirement and the rest is met through imports. Despite the low overall oilseed production presently, the country has a potential not only to become self-sufficient in but to produce surplus oilseeds simply by following the improved low-input technologies of oilseeds production and by a proper delineation of government policies favorable to oilseeds production. These low input technologies have demonstrated 14-100% increase in seed yield over the existing practices under different conditions (DOR, 2005).

3. Biofuels & Low Cost Feedstock

Profitability of biofuels depends on the availability of low-Cost feedstock. Feedstock costs are the most significant cost of biofuel production, ranging from 37 percent for sugarcane-based ethanol in Brazil in 2003-04 to 40-50 percent for corn-based ethanol in the United States. Sugar beets represented 34 percent of the cost of sugar-based ethanol production in the EU. With rising commodity prices, these cost shares are even higher now. Another major cost component is energy, which may account for as much as 20 percent of biofuel operating costs in some countries.

The ratio of crude oil prices to feedstock prices offers a simple indicator of the competitiveness of biofuel made from various feedstock. The ratio of crude oil to corn prices, for example, rose sharply after 2004 as oil and ethanol prices increased and corn prices were stable. But the ratio dropped sharply after September 2006, making biofuels less cost competitive.

Biodiesel producers in Europe and Southeast Asia also faced declining competitiveness as soy and palm oil prices rose in 2006-07. World sugar prices, on the other hand, declined by 50 percent from 10-year highs in 2006, boosting relative prospects in Brazil's ethanol sector. In such a situation species like Pongamia and use of its oil in biofuel production are promising.

4. Potential of Pongamia as Biofuel

At a time when society is becoming increasingly aware of the declining reserves of oil for the production of fossil fuels, it has become apparent that biofuels are destined to make a substantial contribution to the future energy demands of the domestic and commercial economies. To this, *P. pinnata* will impact most significantly through the extraction of seed oil that can be used in the manufacture of biodiesel (Scott 2007). The potential of *P. pinnata* oil as a source of fuel for the biodiesel industry is well recognized (De and Bhattacharya, 1999; Azam et al., 2005; Karmee and Chadha, 2005). Moreover, the use of vegetable oils from plants such as *P. pinnata* has the potential to provide an environmentally acceptable fuel, the production of which is greenhouse gas neutral, with reductions in current diesel engine emissions (Raheman and Phadatare, 2004). Importantly, the successful adoption of biofuels is reliant on the supply of feedstock from non-food crops with the capacity to grow on marginal land and not destined to be used for the cultivation of food crops (Hill et al., 2006). *P. pinnata* is a strong candidate to contribute significant amounts of fuel feedstock, meeting both of these criteria.

The seeds of *P. pinnata* contain 30 to 40% oil (Nagaraj and Mukta, 2004), which can be converted to biodiesel (fatty acid methyl esters.. FAMES) by esterification with methanol in the presence of KOH. The predominant fatty acid is oleic acid (C18:1; 45 to 55%) with palmitic acid (C16:0; 5 to 15%), stearic acid (C18:0; 5 to 10%) and linoleic acid (C18:2; 15 to 20%), and to a much lesser extent arachidic acid (C20:0), eicosanoic acid (C20:1), behenic acid (C22:0) and lignoceric acid (C24:0).

The composition of the seed oil and the properties of the FAMES meet North American and European industry standards (Azam et al., 2005; Karmee and Chadha 2005). These properties include the saponification number (196.7 for *P. pinnata*), which indicates the relative fatty acid chain length of the FAMES; the iodine value (80.9 for *P. pinnata*), which is a measure of the total number of double bonds amongst the respective fatty acids; and the cetane number (55.84 for *P. pinnata*), which gives an indication of ignition quality of the fuel. Other important properties of *P. pinnata* FAMES are the viscosity (3.8 to 4.8 mm²/s at 40°C), flash point (135 to 150°C), pour point (2.1°C), and cloud point (8.3°C). Of these, the pour point, which is the lowest temperature at which oil will flow, and the cloud point, which is the temperature that will lead to separation of dissolved solids from the oil, are critical to the implementation of biodiesel use in temperate and cold climates. In the case of biodiesel from *P. pinnata* the values for the pour and cloud points are satisfactory for tropical and some temperate regions.

However, if this product is to find a market in cool and cold regions there needs to be improvement in these properties. Achieving this goal will require a

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comprehensive understanding of seed oil biosynthesis and the probable modification of seed oil composition through genetic manipulation.

Properties of Pongamia oil

Property	Diesel	Pongamia oil	Jatropha oil
Viscosity 30 °C	3.6	15	52. 5
Specific gravity at 15 °C	0.87	0.85	0.92
Carbon residue	0.15	0.50	0.64
Calorific Value	40-44	37-38	36-37

Source : www.techno-prenuer.net

Characteristics of Pongam oil

%

Character	Value
Density	0.92gm/cm ³
Acid value	5.06 mg KOH/gm
Saponification value	187 KOH/gm
Unsaponifiable matter	2.6 w/w percent
Iodine value	86.5 g
Oil content	27-40

Fatty acid composition of Pongamia oil

Palmitic acid	11.65
Stearic acid	07.50
Oleic acid	51.59
Linoleic	16.64
Eicosenoic acid	01.35
Dosocasnoic acid	04.45
Tatracosanoic acid	01.09

Source : www.techno-prenuer.net

For harnessing the potential of wild tree bearing species like Pongamia innovative ways of using the existing potential and developing new local level institutions are very important. In case of such TBOs the resource could be available from wild, could be developed through plantations and a combination of both could be used to address many environmental and poverty issues. In India two such approaches have been developed by NGOs and research institutions that are discussed below.

5. Potential as Bio- energy through Sustainable Harvesting of Wild Stock and Village Level Enterprise

Growing energy needs, coupled with increasing international oil prices, are forcing India to tap into renewable energy resources to address the energy crisis. The Government of India launched a national programme to promote the large scale cultivation of the plants *Jatropha curcas* and *Pongamia pinnata* for biodiesel production. However, the programmes are long term and need time to reach the farmers in remote areas. In addition, the current subsidy provisions for kerosene to those below the poverty line, diesel to fishermen and electricity at subsidized or free cost to farmers for irrigation are faced with inefficient public distribution systems leading to widespread shortage of energy resources in rural areas.



Oil Expeller for extraction of Pongam oil



Dried Pongam seeds

To ease these barriers through the utilization of existing natural resources, the Applied Environmental Research Foundation (AERF), India has been working since 2005 to set up village/cluster level biodiesel resource centers to meet local energy demands in Alibaug and Mhasala blocks of Raigad district of Maharashtra. In 2007, through Global Actions Programs Fund provided by the Global Village Energy Partnership (GVEP), the AERF reached over 70 villages with a potential to create income generating opportunities through *Pongamia* seed collection activities and employment at the resource centers (Rai & Sarnaik 2009).

The central focus of setting up the biodiesel centers was to exploit the already existing *Pongamia pinnata* trees for extracting oil either for direct fuel use or

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production of bio diesel. The centres established through the intervention were successful because

1. The species Pongamia pinnata was known to local people and an indigenous species with lot of ethno botanical uses.
2. The income generation was based on existing resource
3. The gestation period of plantations and anxiety about the yield were not there.
4. Supply chains were established using the existing institutions like Local Self Help Groups or Village Forest Protection Committees.
5. High awareness and demonstrations through the intervention.
6. The intervention has been based on long term scientific resource assessment of Pongamia pinnata from the region.
7. The intervention has created income generation opportunities through seed collection, management of the centre, Pongamia nursery and plantations on the wasteland.

Projected benefit on account of switching to greener fuel in rural setup.

Agriculture Machinery	Power (HP)	Usage (hrs/yr)	Diesel consumption (liter/hr)	Current diesel price (Rs/liter)	Annual fuel cost (Rs)	SVO price at the Center/ (Rs/liter)	Saving due to substitution by SVO (Rs)
Power tiller	13	500	1.5	40	30,000	35	3750
Irrigation/drinking water pump	5	1000	0.75	40	30,000	35	3750
Tractor	35	600	4	40	96,000	35	12000
Floor mill	3.5	800	0.75	40	24,000	35	3000

(Source : Rai & Sarnaik 2009)

The local enterprise of Mahajane village (Mhasala Block) has successfully entered into third year and the amount of Karanja oil being used as substitute for diesel run machines like Mills, irrigation pumps and power tillers is increasing.

6. Honge Oil as Substitute to Diesel : Karnataka Experience

In India, at least eleven vegetable oils were tried as diesel substitutes in Calcutta in the 1930s. The use of vegetable oils in diesel engines did not become popular because they were more expensive than fossil fuels at that time.

Sustainable Transformation of Rural Areas (SuTRA), a programme unit of the Society for Innovation and Development in the Indian Institute of Science, Bangalore , India carried out detailed work with regard to use of Pongamia pinnata oil (Honge as it is locally known) oil as a replacement for diesel in diesel engines and also the prospect of producing larger quantities of honge oil in rural areas.

Most of the physical and chemical properties of honge oil were similar to those of diesel, though the 'Conradson carbon residue' is higher in the case of honge. This may call for frequent maintenance of the fuel injector. Considering that diesel fuel is often adulterated with other fuels and oils such as kerosene, the use of honge oil may not cause problems that are worse than those being experienced already. Honge oil has to be preheated since the viscosity of the oil is much larger than that of diesel at room temperature. The power output of the diesel engine remains almost the same, though the calorific value of honge is slightly lower. It is argued that honge oil will be less expensive than diesel in rural areas if the value of the cake, which is a good fertilizer, is taken into account .



One hectare of honge plantation could yield 10 tones of seeds which can yield a gross revenue of Rs 40,000 (which is good revenue for dry land), provided high yielding plants are selected (Shrinivasa 2001) . It is suggested planting seedlings a hundred times more densely than is normally required (which is

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about a hundred trees per hectare). Though the yield per plant may be less in the earlier years, this is compensated for by the higher density.

However, as the plants grow, weaker ones have to be selectively culled. It is clearly proven that biofuels protect the environment and the experiments conducted at SuTRA have proved that honge oil can be used without any harm to the engine and, more importantly, the use of honge oil is also economical in rural areas.

Available numbers on yield (2500 kg of oil per hectare per year) and efficiency (4 kh per kg of oil in 1 MW generators) indicate that 10 million hectares of plantation could lead to a generation of 100 billion kWh of electricity or replace 25 million tones of diesel fuel. Cost of plantation at Rs 15,000 per hectare would amount to Rs 15,000 crores, most of which could come as voluntary contribution in kind from the farm sector to improve its own income (Shrinivasa 2001) .

Tree-based oilseeds hold great promise to the rural sector to meet its energy and fertilizer requirements in adequate measure. The potential for consequent increase in primary production from land itself could reshape Indian economy to see better days. The path advocated being environmentally benign makes it even more interesting from a global point of view.

7. Pongamia Based Microenterprise

Indigenous production of Pongamia oil could save foreign exchange worth of several million dollars and also generate employment opportunities in rural areas of India and other developing countries. Such plantations could generate employment opportunities for land less men and women, tribal communities, and small farmers. Especially women self-help groups in rural areas can generate additional income from selling Pongamia seed oil and press cake after oil extraction.

Powerguda was selected for assistance under the IFAD- funded Andhra Pradesh Participatory Tribal Development Project. The Integrated Tribal Development Agency (ITDA), Adilabad district requested International Crops Research Institute for the Semi- Arid tropics (ICRISAT), Patancheru, Andhra Pradesh to provide technical support for raising the income levels in the village by introducing Integrated watershed Management technology (Wani & Sreedevi 2004).

Powerguda a tribal village was selected for the case study because it suffered from many social, economic and natural resource problems. The village comprised of indigenous people who lived in poverty. The productivity was low on agricultural lands. Therefore, the people migrated to nearby towns in search

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of work. At the same time, the community decided to overcome their problems by working with the local government.

Pongamia seed collection drive by villagers Songhar ,Coastal Maharashtra



As a supplementary activity, Powerguda discovered a new income generating activity in raising Pongamia nursery. An additional investment was made by ITDA in an oil extracting machine (worth Rs. 375,000) to support income generating activities of the community.

This oil mill has become an important source of income to the village. The women earn Rs.2 kg-1 Pongamia seed crushed with machine. The plant has the capacity to crush 50 kg seed h-1. Powerguda became an environmental pioneer by planting Pongamia seedlings and when it sold the equivalent of 147 t of carbon dioxide in verified emission reduction to the World Bank. To neutralize the emissions from air travel and local transport by the participants of international conference held in Washington from 19-21 October 2003, the World Bank paid US\$ 645 to Powerguda women self help groups.

8. Limitations to Large Scale Plantations

Tree-borne minor oilseeds have been accorded very high priority as a source material for biodiesel production in the country. India is endowed with a vast potential for oilseeds of tree origin, the important of them being sal, mahua, neem, rubber, karanja, kusum, undi, dhupa, etc. These oilseed-bearing trees are found widely and distributed throughout the country. The present availability of oilseeds from them is estimated to be about 5 million tonnes annually. However, only 20% of the total availability is utilized for commercial applications (Kumar, 2003).

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The availability of TBO can be enhanced considerably without any extra land and inputs if proper network for procurement from seed collectors is established. There is a considerable scope to enhance the collection of seeds from the existing trees by developing infrastructure facilities such as seed/produce procurement centers equipped with facilities for drying,

Pongamia pinnata Earns Carbon Credits in Rural India

Chalbardi is a village of twelve families, four hours' walk from the nearest road in the Adilabad district of Andhra Pradesh, India. In April 2001, the village obtained a 7.5 kVA generator fuelled using biodiesel produced by the village. The citizens of Chalbardi collect the seeds of *Pongamia pinnata*, which is found in the nearby forests. The seeds are then pressed into oil and used directly in the diesel generators. Using 5-6 liters of pongamia oil, Chalbardi can generate 10-12 kW of electricity for 3-4 hours each evening to light each home. In March of 2003, Chalbardi sold 900 tons of CO₂ emission-reduction credits from the project to a European carbon trading firm, 500ppm. Chalbardi received Rs. 200,000 for the sale of the credits, which they partially re-invested in new *Pongamia* saplings. Modelling themselves after Chalbardi's success, four neighbouring villages recently planted 100,000 *Pongamia* trees around agricultural fields with the aim of producing *Pongamia* oilseeds.

Also in Adilabad, the village of Powerguda planted 4500 *Pongamia* trees in 2002 along the edges of their agricultural fields to produce oilseeds. The villagers collect and process the seeds, and they produce enough *Pongamia* oil to power their generator and sell excess to local transport companies as a fuel additive for diesel buses. In October 2003, the group sold 147 tonnes of CO₂ emissions credits to the World Bank for US\$645, investing the money in a *Pongamia* nursery and purchasing 10,000 additional saplings.

In 2002, a report by Community Forestry International concluded that the heavily forest dependent communities in Adilabad District would be good candidates for CDM investments in reforestation and afforestation projects. The degraded teak and dry deciduous forest species in the region regenerate vigorously with relatively low-intensity silviculture, and above-ground carbon sequestration rates for degraded teak sites and 5-7 metric tonnes of carbon per hectare per year. The report and these successful pilot projects suggest that CDM projects could provide a long-term source of funding for rural Indian communities interested in forest restoration, with potential for credits from both CO₂ emissions reductions and carbon sequestration projects.

Sources: D'Silva et al. 2004; Poffenberger 2002

raw oil to the biodiesel processing plant. This should result in reasonable remuneration to the primary seed collector and also help in getting a quality product by reducing losses caused due to delayed and improper handling of the material at different stages in the existing trade of TBO in India.

Apart from the existing trees in the country, there is 60 million hectares of wasteland, of which 50% can be suitably used for growing TBO plantations like

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Jatropha & Pongamia . With the recent central government drive to produce biodiesel from TBO, many state governments in India , have given high priority to plantations of Jatropha for biodiesel production. Information from various sources indicates that area under Jatropha plantations in the country has gone up to 20,000-30,000 hectares. Governments of states like Chhattisgarh, Gujarat and Madhya Pradesh have drawn up plans to take up Jatropha plantations on massive scale. However at the same time indicators of success of Jatropha in the areas other than arid zones in Gujarat and Rajasthan are not very encouraging and the investments in such large scale plantations are very high compared to the yields and net profits. This is mainly because of the myth that these plantations thrive without irrigation and the overestimated yields. Whereas Pongamia a native tree of India has better potential due its availability. It is possible in case of Pongamia to tap the potential of existing resource and then slowly take up plantations where ever necessary.

Pacific Renewable Energy Company, from Australia is in a process of large scale Pongamia plantations. The Pongam oil will be used for production of biodiesel as a strategy to combat the oil shortages in future and to get benefits like carbon credits.

Many countries are currently looking at growing high-yielding crops for the production of biofuels as alternatives to traditional fuels (petrol and diesel) to address imminent energy shortages and reduce impacts of climate change. This usually involves the importation of foreign (i.e., alien) species of plants that are known for their fast and productive growth. If these initiatives are not carefully assessed, however, promoting the cultivation of some popular species for biofuel production will increase two of the major causes of biodiversity loss on the planet: clearing and conversion of yet more natural areas for monocultures, and invasion by non-native species (Chapin et.al 2000).

Habitat conversion is already the leading cause of biodiversity loss worldwide, and limiting the enthusiastic cultivation of new crops to areas already converted is not an easy task. The issue addressed here, though, is that some of the most commonly recommended species for biofuel production, particularly for biodiesel, are also major invasive alien species in many parts of the world.

Thus, their likelihood of becoming invasive needs to be assessed before being cultivated on a large-scale for biofuel production in new areas. Some of these species are spread by birds, small mammals and other animals, making their control difficult or impossible, with impacts increasing over time and long-term production prone to greater financial losses than gains.

It has been now a well known fact that Pongamia pinnata has huge potential for production of biofuels . However raising large scale plantations has been in question. In countries like Australia experiments with scientific risk assessments

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have been carried out before introducing Pongamia as a source of biofuel for large scale cultivations. In case of Pongamia pinnata, the risk of its invasion is comparatively low as it being a long gestation tree species. The risk assessments are extremely important before it is promoted beyond its natural areas/countries of distribution.

9. Environmental Services through *Pongamia pinnata* as a Source of Bioenergy

There has been a debate in Countries like India and African countries like Nicaragua about the right choice of the species for bioenergy. The two candidates were Pongamia and Jatropha. It has been now clear with enormous scientific and grass root evidence that Pongamia is far better than Jatropha. In some parts of the world (GTZ report) Jatropha never fulfilled the expectations on many fronts including the environmental considerations.

The pongamia on the other had has been considered environmentally better and could provide many ecosystem services through the large scale plantations or as a small holder supplementary crop. Some these services are briefly disused below.

Erosion control: A preferred species for controlled soil erosion and binding sand dunes because of its extensive network of lateral roots.

Shade or shelter: Grass grows normally beneath the tree so it has been planted for shade in pastures. *P. pinnata* is grown as a windbreak for tea plantation in Sri Lanka.

Reclamation: Because it tolerates moderate levels of salinity, Pongam is an ideal candidate for recovering a variety of wastelands such as saline soil reclamation. It is also used in reforestation of marginal land.

Nitrogen fixing: Nodulation is reported on Pongam. In nurseries and fields the presence of nodules on uninoculated Pongam seedlings is common. Therefore, this species may not be specific in its Rhizobium strain requirement. It nodulates and fixes atmospheric nitrogen with Rhizobium of the cowpea group.

Soil improver: Incorporation of leaves and the press cake into soils improves fertility. Decomposed flowers are valued in the tropics as rich nutrition for special plants, especially when grown in greenhouses.

Apiculture: *P. pinnata* flowers are considered a good source of pollen for honeybees in India and they yield adequate nectar.

Insecticide & manure : The press cake, when applied to the soil is valued as a pesticide, particularly against nematodes. In rural areas, dried leaves are stored with grain to repel insects. Pounded and roasted seeds used to be utilized as fish

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poison. The by-product (press cake) of Pongamia seed oil extraction process has been tested as an organic source of plant nutrients as it contains 4.0% N, 1.0% P, 1.0% K. On farm trials for using seed cake for oil amendment were conducted in Adilabad district in farmer's fields.

The preliminary trials clearly indicated that the use of nutrient rich press cake enhanced the soil fertility, nutrient availability and yield of crops like maize and soybean.

Oil Seed Cake for Increasing Crop Yields

Grain Yield response of Maize to the application of Pongamia press cake and inorganic fertilizers

Treatment	N Applied (Kg-Ha ⁻¹)	Yield (kg ha-1)	% increase over farmers' practice	Net benefit over farmers' practice (Rs. ha-1)
Farmer's practices DAP 250 kg	40	1200	---	--
Pogamia press cake (1800)	71	2240	87	2325
Fertilizer Urea 200Kg	92	2390	99	6075
Pongamia cake 900kg - Urea 100kg	81	2560	113	2925

(Source Wani , ICRISAT 2006)

Oil Seed Cake for Increasing Crop Yields

Grain Yield response of Soyabean to the application of Pongamia press cake and inorganic fertilizers

Treatment	N Applied (Kg-Ha ⁻¹)	Yield (kg ha-1)	% increase over farmers' practice	Net benefit over farmers' practice (Rs. ha-1)
Farmer's practices DAP -100kg	16	900	---	--
Pogamia press cake (1800)	12	1340	49	4230
Fertilizer Urea 200Kg	23	1450	61	6800
Pongamia cake 900kg -Urea 100kg	17	1650	83	7950

(Source Wani , ICRISAT 2006)

10. Issues Requiring Policy Guidance

Government policies, motivated by concerns about energy security, high oil prices, greenhouse gas (GHG) emissions and various vested interests, are driving the latest expansion in the global biofuels industry. This is most evident in Brazil, the USA and the EU, but increasingly, developing countries are moving in a similar direction – creating new markets for biofuels by adopting policies, mandates and targets aimed at stimulating domestic biofuels production. (Anonymous 2008 CGIAR)

Several countries in the world have active biodiesel programmes. They also have provided legislative support and have drawn up national policies on biodiesel development. France is the world's largest producer of biodiesel; its conventional diesel contains between 2-5% biodiesel and that will soon apply to the whole of Europe. Soya based biodiesel is being produced in USA. Rape seed based biodiesel is in Germany. Germany has more than 1,500 biodiesel filling stations. Sunflower based biodiesel has made good success in France & UK.

The cultivation and management of *Jatropha* is poorly documented in South Africa and there is little field experience available. Currently, growers are unable to achieve the optimum economic benefits from the plant. The markets for the different products have not been properly explored or quantified, nor have the costs or returns (both tangible and intangible) to supply raw materials or products to these markets. Consequently, the actual or potential growers including those in the subsistence sector do not have an adequate information base about the potential and economics of this plant to make decisions relating to their livelihood, not to mention its commercial exploitation.

The stakeholders of the bioenergy sector are mainly governments, global programmes and conventions driving the development of the sector, priorities of the nations, global development agencies, local institutions, NGOs and local farmers, consumers, industry.. the least can go on. However there is a need to consider the interests of various stakeholders and the stakes we all have in contributing to universal phenomenon like climate change. As stated in the introduction, it is the energy sector that has been changing and guiding the development of world as it is the prerequisite of any new technology. In such a case it is extremely difficult to find the synergy among all the stakeholders .To address such situations the understanding of climate change and appropriate policies are important. Some of the policy issues are discussed below.

10.1 Production and Processing

Compared to oil refining, biofuel production is more decentralized, requires far more manpower and can be processed through a variety of technologies. Today,

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first-generation technologies are applied to process the edible part of plants. In future, second-generation biofuels will be derived from any cellulose-rich material, enabling the large-scale conversion of non-food products.

First-generation technologies are well known and established. Ethanol is produced through fermentation of sugar, which can also be derived from starch using enzymes. Pressed vegetable oils can be used as a fuel additive to diesel, without further processing. The chemical process of transesterification, however, produces a higher-quality fuel. Valuable byproducts such as bagasse can be used as a source of electricity, heat, fertilizers or animal feed (Greiler 2007).

Second-generation technologies are under development and should reach commercial scale within 10-15 years. They make additional use of lingo-cellulosic carbon as contained in food crop. Cellulose is the primary component of the solid structure in all plants. Bagasse is a residue from sugar manufacturing that is burned to produce heat and electricity in the ethanol manufacturing process. Woody biomass can also be converted into synthetic biodiesel. Most research and development is done in OECD countries, where some pilot plants already exist. The advantages of second generation technologies are that:

- They have a higher potential to reduce greenhouse gases.
- Feedstock is much more abundant than food crops and does not compete with the latter.
- They require less agrochemical inputs and exert less strain on land and water resources.
- Second generation technologies can reduce land degradation.

Among the disadvantages are those:

- They use advanced patented technologies which are copyright protected.
- They usually require large-scale plantations.
- Initial investment costs are high.

In future, economically viable second-generation technologies should lead to an important expansion of global biofuel production. Still, low-cost biofuels from tropical countries are expected to remain competitive.

National Missions in India

A National Mission on biodiesel has been proposed by the Govt. of India comprising six micro-missions covering the essential aspects of plantation, seed procurement, oil extraction, transesterification, blending & trade and R&D. Indian Oil has worked on establishing the production parameters of transesterified jatropa oil and use of biodiesel in its R&D Centre at Faridabad. They have been using a laboratory scale plant of 100 Kgs./day capacity for transesterification; designing of larger capacity plants is underway. Production of bio-diesel in smaller plants of capacity e.g. 5-20 Kgs./day may also be started in villages.

10.2 Climate Change and Promotion Biofuel Crops

From an environmental perspective, the promotion of biofuels aims at reducing global greenhouse gas emissions to limit climate change. Plants grown to produce biofuels absorb as much carbon dioxide during photosynthesis as biofuels release during combustion. In this regard, the key question is how much GHG is emitted during the whole biofuel production chain, taking into consideration the emissions from cultivation, extraction, transport, processing, distribution and combustion. The GHG balances of biofuels vary massively, ranging from more GHG released than fixed by the plants, to 90 percent reduction when substituting fossil fuels. The main factors influencing GHG balances are:

- Previous use of the land where biofuel crops are grown (forest, peatlands).
- Choice of crop and region of cultivation.
- Cultivation method (use and volume of agrochemicals and farm machinery, etc.).
- Processing system (type of energy required, energy efficiency).

The optimal crop, cultivation method and means of processing for each context have to be found. Analytical tools such as Life-Cycle Analysis (LCA) can help identify the best environmental alternatives, however, social parameters have not yet been integrated in this tool (Greiler 2007). Clear guidelines are required to use the biofuel plantations as CDM and proposals of carbon credit.

10.3 Public Private Partnerships

The biofuel industry is booming, and corporations are jumping into this promising market. The automotive and fuel industry is particularly interested in liquid biofuels, as this form of renewable energy can be used in existing engines and distributed through the existing distribution channels for fossil fuels. Recently, the British company NRG Chemical Engineering invested 1.3 billion USD in biofuel plantations and processing plants in the Philippines; DaimlerChrysler is running a pilot program for Jatropha-based biodiesel in India; Brazil and the United States are making large investments in Latin America. The UBS recently created the first biofuels index and Ernst & Young released its Biofuels Country Attractiveness Indices, which rank countries in terms of their commercial attractiveness to biofuels (without taking energy efficiency or social aspects into account). The present policies for such private sector partnerships are restricted to catering the large industry sector and agro ventures. However there is also a scope to provide policy support to medium and small enterprises at local level to work with the farmers and grassroots institutions.

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A National Mission on biodiesel has been proposed by the Govt. of India comprising six micro-missions covering the essential aspects of plantation, seed procurement, oil extraction, transesterification, blending & trade and R&D. Such initiatives must also include the public and private sector partnerships. Such partnerships will have the capacity to lead and guide the Stakeholders dialogue making the biofuels programmes sustainable for long run and environmental friendly in the real sense.

As most social and environmental costs and benefits of biofuel production and use are not priced in the market, to ensure a generally favorable outcome, clear and comprehensive public policy choices are critically needed. Providing benefits from biofuels in developing countries will require participatory planning involving local communities, understanding food production and consumption patterns, livestock grazing, natural resource settings, local and regional energy needs, and striking a balance between different options. Development agencies and NGOs also have a key role to play in the booming biofuel sector to ensure that the poor can benefit from the new market and from energy services, without increasing their vulnerability.

11.Conclusion

1. Pongamia is underutilized and has a large potential for use as biofuel.
2. Being a tree species , the plantations of Pongamia will help much needed carbon sequestration .
3. In many tropical countries Pongamia grows naturally and there is a need to conduct the region wise resource assessments to understand the actual potential for the use of available trees.
4. Pongamia plantations and nurseries can provide income to rural poor .
5. There is a need to conduct research on yields, selection and improving the yields.
6. There is also a need to conduct research on provenance trails, and agro forestry techniques as *Pongamia pinnata* naturally occurs in range of geographical conditions and performance in each for oil production could be different.
7. The clear policy for TBOs at national and global level, are required to promote the Pongam oil as the feedstock for bio fuel.
8. Exchange of information about the use of *Pongamia* is necessary. A long term global action research programme to look at integrated approach to address energy issues and promoting biofuels with Pongamia as a front runner will help to achieve such exchange.
9. Due to its use for biofuel production the cutting & clear felling of *Pongamia* for fuel wood stops. It contributes positively to the conservation spp. In the wild.
10. Pongamia has been successfully used and demonstrated in India and Australia as important biofuel species .Successful regional country wise

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case studies for learning about the species and its potential in the biofuel markets will help policy makers to consider *Pongamia pinnata* as important candidate.

11. In meeting the future demands for biofuel, it will be important to establish extensive plantations comprising elite varieties of trees. This challenging task will require tools in the fields of genetics, molecular biology, plant propagation and agronomy that will enable this important legume to be fully characterized, and for optimal yields of oil to be achieved.
12. Stakeholders consultations to promote pongamia at global, national and regional level are essential.

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Annex I

Members of the genus *Pongamia*

There are approximately 30 species in this genus:

P. acuminata · *P. amoena* · *P. atropurpurea* · *P. caerulea* · *P. cana* ·
P. cassioides · *P. chinensis* · *P. coriacea* · *P. elliptica* · *P. elongata* · *P.*
extensa · *P. ferruginea* · *P. fruticosa* · *P. galedupa* · *P. glabra* · *P.*
grandifolia · *P. macrophylla* · *P. madagascariensis* · *P. marginata* · *P.*
maritima · *P. ovata* · *P. pinnata* (Poonga-Oil Tree) · *P. piscatoria* · *P.*
piscidia · *P. racemosa* · *P. religiosa* · *P. sinuata* · *P. taiwaniana* · *P.*
tetraptera · and *P. velutina*