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Pongamia pinnata (L.): Composition and advantages in agriculture: A review

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Abstract
Pongamia (*Pongamia pinnata*) is a multipurpose leguminous tree containing non-edible oil grows throughout the India. Pongamia cake has rich source of minerals, amino acids, also contains secondary metabolites. Pongamia oil contains fatty acids, Pongamia leaf contains nutrients. *Pongamia pinnata* has a high nutritious value with macro and micronutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc, copper and iron as an excellent fertilizer source in organic agriculture. Historically, this plant has long been used in India and neighboring regions as a source of traditional medicines (cough, cold, mental disorders, leprosy, diarrhea, ulcers etc.), as a fodder and feed, as a green leaf manure, as a timber, as a fish poison, as a soil binder, as a soil reclaimer, as a biofuel and also pollen source for mainly honey bees. Pongamia cake has a good soil nutrient source improves soil fertility. Oil extracted from the seeds of Pongamia is used in agriculture, pharmacy and as a biofuel. It has similar insecticidal properties as neem oil and acts against a number of pests and insects. Karanjin is the main active ingredient of Pongamia oil. It acts as an acaricide and insecticide while the cake (a byproduct after extracting oil) was found to be rich in all plant nutrients used as a source of plant nutrients.

Keywords: Agriculture, pongamia oil, pongamia cake, biofuel

Introduction
Pongamia pinnata (L.) Pierre (Family: Leguminosae) is an important non-edible minor oilseed tree that grows mainly in the semiarid regions. It is probably originated from India and grows naturally in India, Pakistan, Bangladesh, Malaysia, Vietnam, Thailand, Florida, Australia, and Sri Lanka and also in northeastern Australia, Japan, Fiji, and the Philippines (Mukta and Sreevalli, 2010) [27]. In India, billions of Pongamia trees exist where Pongamia trees are cultivated commercially and seed is available from December to April.

Classification
Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida
Order	:	Fabales
Family	:	Leguminosae
Genus	:	*Pongamia*
Species	:	*pinnata*

(Sangwan *et al.*, 2010) [42].

Botanical and Chemical Characteristics
Pongamia pinnata is a very fast-growing medium size plant with an average height of 30-40 feet and spreads canopy for casting moderate shade (Orwa *et al.*, 2009) [32]. *Pongamia pinnata* has a varied habitat distribution and can grow in a wide range of conditions. It can grow in various types of soil like alkaline, salty, sandy, clay, stony and waterlogged soils and also it shows high tolerance against drought bearing temperature up to 50°C. The trunk is usually short with a diameter of more than 1.64 feet. Pongamia has a deep and thick taproot system with several secondary lateral roots (Daniel, 1997) [10]. The alternate, compound pinnate leaves consist of 5 or 7 leaflets which are arranged in 2 or 3 pairs and a single terminal leaflet. Leaflets are 5-10 cm long, 4-6 cm wide, and pointed at the tip. The bark is thin and gray to grayish-brown in color with yellow on the inside where the tap root is thick and long. Pea-shaped flowers are generally 15-18 mm long and pink, white or light purple in color (Sangwan *et al.*, 2010) [42]. The elliptical pods consist of single seed inside the thick walled pod shell which are 3–6 cm long and 2-3 cm wide. The pods are dried in sun and the seeds are extracted by thrashing. Seeds are light brown in color with 1.0-1.5 cm length.

About 9-90 kg of seed pods can be obtained from one tree which yields up to 40% oil per seed and around 50% of this oil is C18:1, which is considered as suitable for biodiesel production. About 8–24 kg of kernels is obtained from one tree which yields 30-40% oil (Lakshmikanthan, 1978; Bringi, 1987) [23, 4]. The seeds naturally exist for about six months. The air dried kernels consist of 19% moisture, 27.5% oil, 17.4% protein, 7.3% crude fiber, 6.6% starch, and 2.3% ash (Bringi, 1987) [4].

Pongamia is a diploid legume with chromosome number 22. The chromosomes are small at mitosis and resemble those of soybean. An estimate of the genome size is around 600-700 mega base pairs per haploid genome. DNA and RNA have been isolated and analysed from leaf and root material. Modern high through-put DNA sequencing techniques (specifically using Illumina SOLEXA technology) have been applied and created large data file sets of Pongamia genomic sequence. For example, using this approach, genes for seed fatty acid biosynthesis and stability and seed storage protein have been isolated from Pongamia and characterized for their developmental expression profile during seed maturation. As an indirect measure of expression mRNA can be quantified for specific Pongamia genes, different tissues and growth conditions.

Oils and proteins can be isolated from seed cotyledons. Oil extracted from seeds is found predominantly in the form of triglycerides, with the major fatty acid being C18:1 (oleic acid; a common component of olive and canola oil). Stearic (C18:0) and palmitic (C16:0) acids, which contribute to a rise in the cloud point are minor components, usually measured at between 9 and 17% of the total fatty acids (Arpiwi *et al*., 2011; Plummer *et al*., 2010; Scott *et al*., 2008a; Sharma *et al*., 2010) [2, 36, 44, 42, 47].

Cultivation of *Pongamia pinnata*

Pongamia pinnata is one of the nitrogen-fixing tree which are predominantly cultivated through seeds. The genetic diversity has been conserved through storage of seeds which is the most common conventional and economical method (Hong and Ellis, 1996) [15]. About 60 × 60 × 60 cm^3 pits are appropriate for planting where the spacing between rows should be 5 m and plant to plant distance is recommended to be 4 m. Generally, three irrigations may be given in a year for better growth and development of the plants.

Propagation

Propagation of Pongamia is primarily done from seed, a process which is labour intensive and not suitable for maintenance of genetically superior lines. Pongamia is an obligate out-crosser with pollination occurring primarily via bees. Thus a pollen donor could include any tree within the distance a pollinator is capable of carrying and transferring pollen (approximately 3 km radius). Once the best performing genetic material is selected, trees must be clonally propagated from stem cuttings or grafting, or via tissue culture.

Chemistry

Pongamia pinnata contains alkaloids like demethoxy-kanugin, gamatay, glabrin, glabrosaponin, kanjone, kaempferol, karangin, kanugin, quercitin, pinnatin, neoglabrin, pongamol, pongapin, b-sitosterol, saponin, and tannin. Air-dry kernels have 19.0% moisture, 27.5% fatty oil (Fatty acid composition: stearic 2.4–8.9%, palmitic, 3.7–7.9%, lignoceric 1.1–3.5%, arachidic 2.2–4.7%, linoleic 10.8–18.3%, oleic, 44.5–71.3%, behenic 4.2–5.3%, and eicosenoic 9.5–12.4%), 17.4% protein, 6.6% starch, 7.3% crude fiber and 2.4% ash. Destructive distillation of the wood yields, on a dry weight basis: charcoal 31.0%, pyroligneous acid 36.69, acid 4.3%, ester 3.4%, acetone 1.9%, methanol 1.1%, tar 9.0%, pitch and losses 4.4%, and gas 0.12 cu m/kg.

Nitrogen Fixation

Pongamia is able to form functional spherical nodules with a broad range of rhizobia belonging to the Bradyrhizobium tribe (Scott *et al*., 2008) [44]. Such bacteria commonly nodulate *Australian acacia* (wattle) species. Their persistence in Australian soils may present a hurdle to establishing highly effective Bradyrhizobium strains for Pongamia that will persist in field situations. Pongamia plants are thought to exhibit the classical legume nodulation response called auto regulation of nodulation (Caetano-Anolles and Gresshoff, 1991; Ferguson *et al*., 2010) [6, 13].

Table 1: *Pongamia pinnata* reproductive and yield variables (Murphy *et al*., 2012) [28]:

Variable	Unit	Range	Average
Time to reproductive maturity	Year	4 to >14	5
Full development of seeds	Months	10-11	10
Flowering episodes per year	Number	1-2	1
Seed production per tree	kg/year	0-30	20
Seed oil content	%	1-45	40
Seed viability	Months	<12	
Tree per hectare	Number	320-500	350
Yield	Tonnes/ha/year		7

Factors which Influences the good growth of *Pongamia Pinnata*

1. Soil and water

Pongamia has been growing on a wide range of soil types like acid soils, sodic, alkaline soils, and heavy clay soils with a sodic subsoil horizon and also reported to grow on a wide range of soil types from stony to clay to sandy (Kesari and Rangan, 2010) [17-18], though it is noted that the plant does not do well on dry sands. Despite tolerance to a wide range of soil types, soil conditions are likely to interact strongly with climate to markedly affect rates of Pongamia growth.

Water requirements for satisfactory rates of seed and oil production by Pongamia are poorly understood, but experts suggested that irrigation is required during the establishment phase of the plantings (first seven years) in dry tropical and subtropical areas, and sometimes subsequently in order to ensure seed set.

Salt tolerance Pongamia is promoted as being able to produce oilseeds on degraded, low productivity or salt-affected land thereby lessening competition for higher productivity land used for agricultural production (Kesari and Rangan, 2010; Odeh *et al*., 2011) [17-18, 31]. The reduction in nodulation with increasing salinity in Pongamia is comparable with *Acacia ampliceps*, another salt-tolerant legume that has been widely used for the purpose of reclaiming salt-affected land (Wilkinson *et al*., 2011) [55].

2. Temperature

Night-time temperatures appear critical in regulating Pongamia phenology. Minimum temperatures are consistently greater than 15°C, at least six months of minimum temperatures > 15°C are required for remarkable foliage, flower and seed production.

3. Frost
Pongamia has been observed to survive and recover from frost events (frost tolerant). Leaf blackening and abscission were observed after the frost but trees were able to undergo profuse vegetative growth again (Mukta and Sreevali, 2009; Prasad and Pandey, 1987) [26, 38].

4. Fertilizer management
Application of fertilizer at the seedling stage probably enhances establishment success and early growth. Addition of macro nutrients like phosphorus, potassium and micronutrients may be required over the 26 long-term to maintain soil fertility.

5. Weed control
Weed control (mechanical and chemical) during the first three years after planting for successful establishment. Seedlings < 30 cm high are very vulnerable to weed overgrowth. Planting of seedlings of 50-60 cm in height will greatly improve survival in the field (Venkatesh *et al*., 2003) [52]. Intercropping with suitable species during the period of establishment (*i.e*. first 3-4 years) may contribute to good weed management.

6. Pests and diseases
Pongamia has been infected by a fungus *Phyllachora pongamiae* (Borah *et al*., 1998) [3] causing a disease known as 'tar spot' (Shivas and Alcorn, 1996). The fungus causes a leaf discoloration but does not appear to cause mortality or seriously impact mature trees. However, it may have more serious impacts on seedlings. Other fungi causing leaf spot and blight recorded on Pongamia in India includes *Fusicladium pongamiae*, *Microstroma pongamiae*, *Cercospora pongamiae* and *Ravenelia hobsoni* (Arpiwi *et al*., 2011) [2].
A number of other potential pests of Pongamia like stem borer, leaf miner, locusts, green ants etc.

Composition of pongamia leaf
Ullah *et al*. (2014) [23] and Khattak *et al*. (2015) [16] explained the nutrient composition of *pongamia pinnata* leaf (Table 2)

Table 2: Nutrient composition of *Pongamia pinnata* leaf:

Parameter	Value (µg/g DM)
Na^{+}	204
K^{+}	197
Mg^{++}	67
Ca^{++}	80
Fe^{++}	42
Mn^{++}	22
Zn^{++}	35
Total soluble phenolic content	1,39,000

*DM: dry matter

Composition of pongamia cake
The seed of Pongamia consists of an outer hull portion (~6 % mass) and an inner kernel portion (~94 %). Following oil extraction, approximately two thirds by weight of the original seed is left as a residual meal or cake, containing 28-34 % crude protein (Vinay and Kanya, 2008) [53]. Main composition of pongamia cake was shown in Table 3. The Pongamia meal or cake (also known as karajin cake) has been used as manure, fungicide and insecticide and mainly in India, on utilisation of this protein meal/ amino acids (Table 5) as animal feed (Kumar and Singh, 2002; Panda *et al*., 2008; Pavela and Herda, 2007; Vinay and Kanya, 2008) [20, 33, 35, 53]. However, the meal contains karanjin (a fluro-flavinoid) and pongamol in the residual oil that make it unpalatable. Vinay and Kanya (2008) [53] reported thatpongamia cake contains anti-nutritional factors such as tannins, phytates, and protease inhibitors that affect rumen metabolites (Table 6) and the digestibility of protein and carbohydrates (Nitrogen digestibility, Table 6).

Table 3: Main composition of Pongamia cake (Kumar *et al*., 2007) [21]

Main Analysis	Composition
Crude protein	26.6 % Dry Matter
Crude fibre	5.6 % Dry Matter
Lignin	2.9 % Dry Matter
Ether extract	11.0 % Dry Matter
Ash	4.9 % Dry Matter

Table 4: Mineral composition of Pongamia cake (Chandrasekaran *et al*., 1989; Gowda *et al*., 2004) [7, 14].

Minerals	Composition
Calcium	7 g/kg dry matter
Phosphorus	6.2 g/kg dry matter
Potassium	2.3 g/kg dry matter
Magnesium	2.4 g/kg dry matter
Manganese	76 mg/kg dry matter
Zinc	199 mg/kg dry matter
Copper	12 mg/kg dry matter
Iron	23 mg/kg dry matter

Table 5: Amino acid composition in Pongamia cake (Ravi *et al*., 2000) [40]

Amino acids	Composition (% protein)
Alanine	3.7
Arginine	4.5
Aspartic acid	8.6
Cystine	3.6
Glutamic acid	15.5
Glycine	3.6
Histidine	3.6
Isoleucine	4.8
Leucine	7.8
Lysine	4.5
Methionine	1.2
Phenylalanine	4.4
Proline	4.0
Serine	4.3
Threonine	3.4
Tyrosine	3.5
Valine	5.9

Table 6: Secondary metabolites and ruminant nutritional value of pongamia cake (Nagalakshmi *et al*., 2011) [29]

Secondary metabolite	Tannic acid	24.6 g/kg dry matter
Ruminant nutritive value	Nitrogen digestibility	85.9 %

Composition of Pongamia Oil
Pongamia oil is extracted from the seeds by expeller pressing, cold pressing, or solvent extraction. Physical properties of crude Pongamia oil was shown in Table 8. The oil is yellowish-orange to brown in color. It is toxic and will induce nausea and vomiting if eaten, but it is used in many traditional remedies. Pongamia oil is fatty acid rich (Table 7). It has a high content of triglycerides, and its disagreeable taste and

odor are due to bitter flavonoid constituents including pongamol, karanjin, karanjachromene and tannin.

Table 7: Fatty acids composition of Pongamia oil (Pandey, 2008) [34]

Fatty acids	Nomenclature	Percentage
Palmitic	C16:0	3.7-7.9
Stearic	C18:0	2.4-8.9
Oleic	C18:1	44.5-71.3
Linoleic	C18:2	10.8-18.3
Linolenic	C18:3	2.6
Arachidic	C20:0	22.2-4.7
Eicosenoic	C20:1	9.5-12.4
Behenic	C22:0	4.2-5.3
Lignoceric	C24:0	1.1-3.5

Table 8: The physical properties of crude Pongamia oil (Pandey, 2008) [34]

Property	Unit	Value
Acid value	mg KOH/g	4-12
Calorific value	kcal/kg	8742
Cetane number		42
Density	g/cc	0.924
Iodine value	g/100 g	86.5-87
Saponification value	mg KOH/g	184-187
Specific gravity		0.925
Unsaponifiable matter	% w/w	2.6-2.9
Viscosity	mm^2/sec	40.2
Boiling point	ºC	316
Cloud point	ºC	3.5
Fire point	ºC	230
Flash point	ºC	225
Pour point	ºC	-3

Applications of *Pongamia pinnata*

All the parts of *Pongamia pinnata* like flower, seed, leaf, root, and so forth have been utilized as a source of traditional medicines, animal fodder, green manure, timber, fish poison and fuel etc.

1. *Pongamia pinnata* Wood

Traditionally, *Pongamia pinnata* wood with a calorific value of 4600 kcal/kg, it is used as fuel in rural areas. The wood is used for stove top fuels, poles and ornamental carvings (Das and Alam, 2001) [11], cabinet making, posts, agricultural implements, tool handles, cart wheels, and some usual activities. The ash produced from burning wood is used for dyeing (Allen and Allen, 1981) [1].

2. *Pongamia pinnata* as Fodder and Feed

The *Pongamia pinnata* leaves contain 43 % dry matter, 18 % crude protein, 62 % neutral detergent fiber, and *in vitro* dry matter digestibility of 50 % and are eaten by cattle and readily consumed by goats. The trees have a significant value in arid regions, however the use is not common. The cake after oil extraction is bitter and unfit for use as a animal feed. It is rich in protein, but posses several toxic flavonoids like 1.25 % karanjin and 0.85 % pongamol alkaloid, resin, mucilage, sugar and tannin. These toxins are oil soluble and most of the toxins are removed during solute extraction of oil from cake with hexane. Short term substitution is required for protein sources, but never serving more than 75 % replacement. The deoiled cakes could be used as poultry feed and cattle feed.

3. *Pongamia pinnata* Oil

Oil is considered the most significant product obtained from the *Pongamia pinnata* seeds. It is a thick, yellowish or reddish-brown oil which has a calorific value of 40.756 MJ/kg, extracted through expeller, solvent extraction, and so forth. The oil is non-edible, bitter in taste, and unpleasant smell and is used for commercial processes as medicine and lamp fuel and for the production of biodiesel. Furthermore, it is used as fuel for cooking, as a lubricant, in leather dressing, as water-paint binder, candles, in soap-making, and tanning industries (Burkill, 1996) [5]. Crude karanjia oil (CKO) has also the application in body oils, salves, lotions, shampoos, hair tonics, and pesticides (Kesari *et al.*, 2010) [17-18]. Pongamia oil showed inhibitory effects on *Bacillus anthracis*, *Bacillus mycoides*, *Bacillus pulilus*, *Escherichia coli*, *Pseudomonas mangiferae*, *Salmonella typhi*, *Staphylococcus albus*, *Sarcina lutea*, *Staphylococcus aureus*, and *Xanthomonas campestris*, but did not inhibit *Shigella* sp. (Chaurasia and Jain, 1978) [8].

4. *Pongamia pinnata* as a Medicine

Even though all parts of the plant are noxious, the flowers and fruits along with the seeds are used in many traditional medicines. Flowers are used to treat bleeding hemorrhoids whereas fruits aid in treatment of abdominal ulcers, tumors, and hemorrhoids. Seed powder reduces fever and helps in treating bronchitis, whooping cough and also prescribed as a febrifuge and tonic. On the other hand, leaves juices aid in treatment of leprosy, diarrhea, coughs, gonorrhea, flatulence, and colds. Bark, which has been used as a medicine to reduce swelling of the spleen. Bark relieves coughs and colds and mental disorder. Root is used as a toothbrush for oral hygiene while root juice is used to clean ulcers. *Pongamia pinnata* oil is capable of causing bleeding to stop when it is applied to a wound, anthelmintic and good in leprosy, piles, liver pain, chronic fever, ulcers (Warrier *et al.*, 1995) [54] and rheumatism arthritis scabies (Prasad and Reshmi, 2003) [37]. The bark yields a black gum that is used to treat wounds caused by poisonous fish. The black malodorous roots contain a potent fish-stupefying principle. the flowers are cleared to have an anti-diabetic actions.

5. Seed Cake as Fertilizer

The pongamia tree (*Pongammia glabra* and *Pongammia Pinnata*) can be found throughout India and tree is popularly known for its medicinal properties, and it is traditionally used for many years. Oil extraction yields a press cake that can be used as a fertilizer or as animal feed for ruminants and poultry (Sreedevi *et al.*, 2009; Scott *et al.*, 2008) [50, 44]. Three main types of pongamia oil cakes are available, namely rotary pressed, expeller pressed and solvent-extracted, the composition of which depending on the degree of decortication and the method of oil extraction (Dutta *et al.*, 2012) [12]. Seed cake is rich in protein nitrogen and is used as green manure to fertilize the land. pongamia oil cake (POC) has 3.2 to 3.7 % nitrogen, 0.22 to 0.23 % phosphorus and 0.65 to 0.68 % potassium is an excellent organic fertilizer. It is also used as a pesticide, especially against nematodes. Besides, the seed cake can be used for biogas production.

6. Rich Source of NPK

Pongamia cake has rich quantity of NPK in organic form. Being totally botanical product it contains 100 % natural NPK content and other essential micro nutrients as well. The pongamia cake is very good to use as organic fertilizers as they are a rich source of NPK which improves soil fertility. The cake when applied to the soil, also has a pesticidal value, particularly against nematodes, and others similar diseases.

As a natural fertilizer, it can be mixed with neem cake pellets to give a synergic result. Manurial values of leaves: nitrogen 1.16 %, phosphorus (P_2O_5) 0.14 %, potasssium (K_2O) 0.49 % and lime (CaO) 1.54 % (Morton, 1990) and Manurial value of twigs: nitrogen 0.71 %, phosphorus (P_2O_5) 0.11 %, potasssium (K_2O) 0.62 % and lime (CaO) 1.58 %. These manures reduces the incidence of *Meloidogyne javanica*.

7. Soil Erosion

Pongamia pinnata trees are usually planted along the highways, roads, and canals to stop soil erosion. The plants develop a lateral network of roots for controlling soil erosion and binding sand dunes. Pongamia has been traditionally used by villagers on slopy uplands to bind the soil (Kumar, 2004) [22].

8. Soil Reclamation

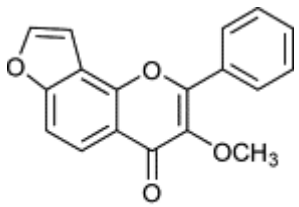
Pongamia is promoted as being able to produce oil on poor, degraded or saline soils (Murphy *et al*., 2012) [28]. Pongamia trees have been used for soil reclamation around coal mines and revegetation in India (Maiti, 2012) [24]. Most importantly, the Pongamia trees can tolerate a wide range of abiotic stresses and improve the soil nutrient status as well.

9. As an insecticide

Extracts of Pongamia have been reported to be effective against insect pests in stored grains and on crops, acting as a deterrent to oviposition and as antifeedants and larvicides against a wide range of pests (Kumar and Singh, 2002) [20]. Water-oil suspension of up to 2 %, has generally been used as a spray to achieve the desired insect inhibiting effect (Pavela and Herda, 2007) [35].

10. Karanjin

Karanjin is extracted from *Derris indica* (Lam.) Bennet (synonym Pongamia *pinnata* (L.) Pierre). Karanjin is a potent deterrent to many different genera of insects and mites in a wide range of crops. Karanjin has a dramatic antifeedant or repellent effect, with many insects avoiding treated crops. It suppresses the effects of ecdysteroids and thereby acts as an insect growth regulator and antifeedant. It inhibits cytochrome P-450 in susceptible insects and mites. Karanjin has not achieved wide acceptance as an insecticide. There is no evidence of allergic or other adverse effects, and it is not expected that Karanjin-based products will have any adverse effects on non-target organisms or on the environment (Copping and Duke, 2007) [9].



Karanjin

11. Flower source for bees

Pongamia pinnata L. (Family: Fabaceae) was a perennial flowering plant, growing as an avenue tree for aesthetics. Pongamia flowers attracted 21 species of pollinators belonging to orders hymenoptera, diptera, thysanoptera and lepidoptera including aves. Megachilid bees were found to be the most abundant and constituted more than 55% of the insects visiting Pongamia flowers (Shankar *et. al*., 2017) [46]. Some of the examples are *Megachile bicolor*, M. *disjuncta*, *M. conjuncta*, *M. hera*, *M. rotandata*, *M. vigilans*, *M. amputata* and *Coelioxys confusus* (parasitic megachilid) was observed to be the prominent pollinators along with that Apidae bees, *Apis dorsata*, *A. mellifera*, *A. cerana*, *Xylocopa latipes*, *Pithites smargdula* and one species each of Halictidae (*Nomia iridipennis*), vespidae, thripidae, syrphidae, muscidae, danaidae, lycaenidae, hespiridae and nectarinidae for nectar and pollen reward (Shankar *et. al*., 2017) [46]. Pongamia flowers may become important floral sources and serve as the reservoir in conservation of pollinators during hot summer.

12. *Pongamia pinnata* as a biofuel

Mature seeds of pongamia have recently gained a great commercial relevance owing to their high oil content, Pongamia seed oils are rich in oleic acid, which may endow the biodiesel products with more desirable fuel properties, which is explored as an alternate source of fuel and energy (Ravikanth *et al*., 2009) [41]. Oil yielding crop plants are very important for economic growth of the energy and agricultural sectors. The oil seeds containing polyunsaturated fatty acids are important source of biodiesel (Sarma *et al*., 2005; Sharmin *et al*., 2006) [43, 48]. These organic seed oils are better than diesel fuels in terms of physico-chemical properties and biodegradability (Scott *et al*., 2008a) [44]. To increase the biodiesel production it is important to have an elite genotype of *Pongamia pinnata* bearing high oil-yielding seeds. The candidate plus tree (CPT) is an individual tree of *Pongamia pinnata* possessing superior morphological characters (height of the tree, girth of the tree, number of leaves g wt^{-1}, number of buds $inflorescence^{-1}$, number of flowers $inflorescence\text{-}^{1}$, number of seeds $inflorescence^{-1}$) than other individuals of the same species (Kesari *et al*., 2008) [19]. *Pongamia 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) [39]. The seeds of *Pongamia pinnata* contain 30 to 40% oil (Nagaraj and Mukta, 2004) [30] which can be converted to biodiesel (fatty acid methyl esters; FAMEs) by esterification with methanol in the presence of KOH.

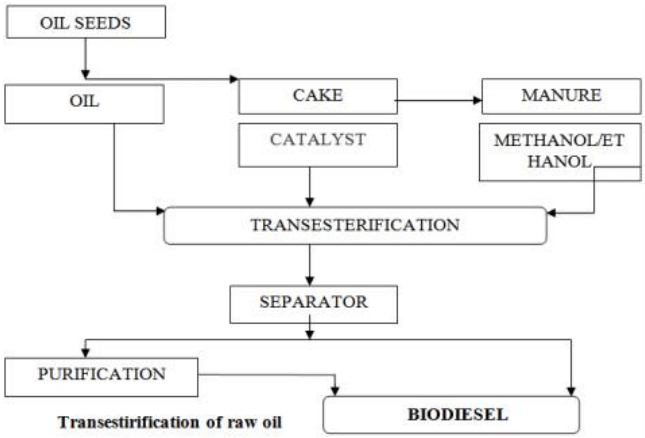


Fig 1: Schematic diagram of Pongamia Biodiesel production

Conclusion

Pongamia pinnata was a versatile resource shows the promising properties for the agriculture like insect pest management, as a biofuel, as a good source of crop macro and micronutrients, as a soil binder etc and medical industry as a anti-microbial, anti-ulcer, anti-diarrhoeal, anti-plasmodial,

anti-inflammatory, anti-oxidantal antiviral properties. Pongamia oil, leaf and cake was found to be the good nutritional value as a soil fertility management, pesticide, acaricide and nematicide in agriculture.

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