Biodiesel has become more attractive as a renewable energy resource because of its eco-friendly, biodegradable nature (Singh and Singh, 2010). The greater demand for petroleum products is due to enormous increase in the number of automobiles and this become the growing problem in many of the developing countries. The crude oil reserves will be available only for few decades, therefore efforts are on the way to find out new alternatives to diesel (Anbumani and Singh, 2010) as depletion of crude oil would cause a major impact on the transportation sector. Biodiesel, a mono alkyl ester of long chain fatty acids prepared from vegetable oils or animal fats, possesses a number of technical advantages over petro diesel, such as derivation from renewable and domestic feed stocks, displacement of imported petroleum, inherent lubricity, essentially no sulfur content, superior flash point and biodegradability, reduced toxicity as well as reduction in most regulated exhaust emissions (Jham et al., 2009).

The viscosity of the biodiesel feedstock can be reduced by dilution, pyrolysis, transesterification and emulsification process (Anbumani and Singh, 2010; Ma and Hanna, 1999). By mixing the vegetable oil with conventional diesel at B10 and B20 proportions, the density and viscosity were found to be nearing to that of diesel. The biodiesel obtained by blending is free from catalyst, water content and other residual chemical. Hence it is safe to the engine. The methyl esters of rubber seed oil was successfully used in existing diesel engines without any modifications. Lower concentrations of biodiesel blends improved thermal efficiency. At higher concentrations of biodiesel in the blend, there was a reduction of smoke density in exhaust gas (Ramadhas et al., 2005). Higher viscosities affect the atomization and combustion process and raise the potential for the formation of engine deposits and higher exhaust gas emissions levels (Ramadhas et al., 2004). Fuels with poor lubricity can cause failure of diesel engine parts that relay on lubrication from fuels such as fuel pumps and injectors (Knothe et al., 2005).

The novel method for screening the biodiesel from vegetable oil of both edible and non-forms is the ultrasonic studies. Ultrasonic velocity of blended and pure biodiesels can be efficiently found out by this method (Gopalakrishna et al., 2010). Cetane number is a measure of ignition delay time. Higher CN is a desirable property in diesel engine, indicates shorter time between ignition and initiation of fuel injection into the combustion chamber. The higher CN is correlated with the reduction of nitrogen oxides and unburnt hydrocarbon exhaust emissions which is important for alleviating air pollution (Srivastava and Prasad, 2000; Mohibbe Azam et al., 2005; Tong et al., 2011).

Knothe et al., (2005) have reported that dissolved solids were in very trace amounts in vegetable oils. The ester formed during the production of bio-diesel reduces energy
content and makes the biodiesel polar through the hydroxyl (-OH) hydrogen bond. The polarity gives the properties of solvency, detergency, wet ability (sticking to metals as a lubricant) and conductivity. Pure biodiesel has excellent anti foam properties than petroleum diesel (Srivastava and Prasad, 2000). The world is confronted with the twin crises of fossil fuel depletion and environmental problems. Due to the shortage of petroleum products, its increasing cost and environmental pollution, efforts are taken to develop alternative fuels especially, to the diesel fuel (Ramadhas et al., 2005). It was reported that the vegetable oils are promising alternative fuels since their properties are similar to that of diesel and are renewable, easily available and environmental friendly (Encinar et al., 2002; Canakci, 2007). Biodiesel is nontoxic, eco-friendly and non-corrosive. Depending upon the climate and soil condition, different countries are using various types of bio-resources for the production of alternative fuel namely the biodiesel.

Similar to petroleum diesel, biodiesel operates in compression ignition engines with little or no modification (Meher et al., 2006). Moreover, biodiesel offers advantages regarding the engine wear, cost, and availability (Dorado et al., 2003; Khan et al., 2009). When burnt, biodiesel produces pollutants that are less detrimental to human health (Lin and Lin, 2006; Mamat et al., 2009). In addition, it provides better lubricity as compared to that of diesel fuel (Knothe, 2005). Combustion of biodiesel fuel in compression-ignition (CI) engines results in lower smoke, particulate matter, carbon monoxide and hydrocarbon emissions compared to diesel combustion while the engine efficiency is either unaffected or improved (Nabi et al., 2009; Qi et al., 2009; Aydin and Ilkilic, 2010). However, these are influenced by a number of factors including lower heating value (Agarwal, 2007), increased viscosity (Hasimoglu et al., 2008), higher density (Raheman and Ghadge, 2007), less calorific value (Szybist et al., 2007), oxygen content (Murillo et al., 2007), auto-oxidation (Ryu, 2010) of biodiesel. In order to minimize the adverse effect of these factors, many researchers added different blending components such as methanol to improve viscosity (Cheng et al., 2008), ethanol to reduce fuel consumption (Aydin and Ilkilic, 2010), additives to reduce oxidation (Ryu, 2010).

Biodiesel inherently provides better lubricity than diesel fuel (Haseeb et al., 2010). However, wear and friction may increase if the fuel is hygroscopic in nature. Biodiesel is such type of fuel, which can absorb moisture and thereby it can increase corrosive wear. In addition, auto-oxidation of biodiesel is most likely prone to influence wear characteristics. According to Knothe and Steidly (2005) and Holser and Harry-O’Kuru (2006) biodiesel always provides better lubricity than that of diesel fuel. Trace components found in biodiesel fuels including free fatty acids, monoglycerides, diglycerides are reported to
improve the lubricity of biodiesel (Jianbo et al., 2005). Oxygen containing compounds such as free fatty acids, esters are superior wear and friction reducing agents (Haseeb et al., 2010). These compounds adsorb or react on rubbing surfaces to reduce adhesion between contacting asperities and thereby limit friction, wear and seizure.

Concerns arise from the fact that biodiesel is more hygroscopic in nature as compared to diesel (Jaroonjitsathian et al., 2009), has higher electrical conductivity (Prieto et al., 2008) and increased polarity and solvency (Prieto et al., 2008; Trakarnpurk and Porntangjitlikit, 2008). Free water in biodiesel is undesirable because it may promote microbial growth and corrodes fuel system components (Klofutar and Golob, 2007; Trakarnpurk and Porntangjitlikit, 2008). The presence of high levels of unsaturated fatty acid methyl esters (FAME) makes biodiesel very susceptible to oxidation as compared to petroleum diesel (Domingos et al., 2007). According to Sarin et al., (2009) the fatty acid methyl ester usually forms a radical next to double bond and then quickly bond with the oxygen from air during oxidation process. This process may change the fuel properties including viscosity, total acid number, density, iodine value, pour point and cloud point. Increased acidity and peroxide value as a result of oxidation reactions can also cause the corrosion of fuel system components, hardening of rubber components and fusion of moving components (Tao, 1995; Monyem and Gerpen, 2001).

2.1 Plant genetic resources as alternate fuels

In India, the main source of energy is obtained from fossil fuels and the demand for energy keeps on increasing. The depleting petroleum fuel resources, price hike, non-renewable nature and the emission of pollutant urges the need for the development of an alternative source of fuel which could be easily available, economic and eco-friendly. One among the alternative renewable fuel is “Biodiesel” which is obtained from vegetable oils. Biodiesel is biodegradable, easily available and also offers lubricity which extends engine life. There are about 400 oil yielding crops in India (Meenadevi et al., 2012). Of the various alternate fuels under consideration, biodiesel derived from vegetable oils appears to be the most promising alternative fuel to diesel (Crabbe et al., 2001; Knothe and Steidley, 2005). More than 95% of the world’s biodiesel is produced from edible vegetable oils (Gui et al., 2008). Therefore, worldwide vegetable oil production was increased many fold (Gunstone, 2002). The most commonly used oils for the production of biodiesel are soybean, sunflower, palm, rapeseed, canola, *Jatropha* and cottonseed (Kose et al., 2002). Since the prices of edible vegetable oils are higher than that of diesel fuel, non-edible vegetable oils are preferred as potential low priced biodiesel sources.
A lot of research work has already been carried out to use vegetable oil both in its pure form and also in modified form. Studies have shown that the usage of vegetable oils in pure form is possible but not preferable (Bari et al., 2002). Biodiesel can be used in pure form (100%) or blended with the conventional diesel fuel up to 20% to create a biodiesel blended fuel for its use in the compression ignition engines (Caio et al., 2006). It can be used as a standalone fuel or blended with petroleum diesel in diesel engines (Arumugam et al., 1998). Biodiesel can be used neat (B100) or at various blend ratios with diesel fuel. A blend of 5% biodiesel (B5) can already be included within existing diesel fuel supplies without identification.

The concept of vegetable oils as fuel is not new. It was proposed by Rudolf diesel at the time of Second World War. He used pea nut oil as a fuel in diesel engine. The major obstacle for commercialization of biodiesel (BD) is its cost. About 70-90% of the cost of biodiesel is contributed to the cost of feed stocks (Canakci and Van Gerpen, 2001). Most of the biodiesels were prepared from edible oils such as soybean (de Oliveira et al., 2005), rapeseed (Jeong and Park, 1996), sunflower (Vicente et al., 2004), safflower (Meka et al., 2007), canola (Singh et al., 2006), palm (Darnoko and Cheryman, 2000; Cheng et al., 2004) and fish oil (El Mashad et al., 2006). Cost of edible oils is higher than Petroleum Diesel. In addition, use of edible oils for biodiesel production leads to food oil crisis. This problem can be overcome by using cheapest, low cost non edible oils such as Jatropha, Pongamia, Madhuca and Azhadirachta as feed stocks for biodiesel production. However, the direct use of vegetable oils as fuel can cause problems to the engine such as poor fuel atomization, incomplete combustion and carbon deposition on fuel injector and engine fouling (Sridharan and Mathai, 1974; Williamson and Badr, 1998; Karaosmanoglu et al., 2000; Encinar et al., 2002). This is due to the presence of higher viscosity (about 11-17 times higher than petroleum diesel) of vegetable oils. Hence the viscosity of vegetable oils can be reduced by several methods which include blending of oils, micro emulsification, pyrolysis and transesterification (Ma and Hanna, 1999). Of these methods, transesterification is widely used for industrial production of biodiesel.

Soap formation reduces the catalytic effect, leads to gel formation and makes the difficulty in separation of glycerol from the product (Guo and Leung, 2003). In this situation, a two step catalyzed method (Zhang et al., 2003; Gerpen and Knothe, 2005 and Wang et al., 2007) such as acid method followed by alkali method was used to prepare the biodiesel from the following non-edible oils like Jatropha, Pongamia, Madhuca and Azhadirachta. Biodiesel is a more attractive alternative fuel to diesel engines. Because, it is a renewable and non-polluted fuel that can be produced from plant and animal fats.
Biodiesel emits low pollutants than petroleum diesel. But the major problem arises for the commercialization of biodiesel is its cost. Since most of the biodiesels were derived from edible oils like soybean, sunflower, rapeseed and palm these oils are essentially edible in India and other developing countries. On the other hand, diversion of edible oils as feed stocks for biodiesel production leads to food crisis. Therefore, research is mainly concentrated on the non-edible oils as feed stocks for biodiesel production to reduce the cost of biodiesel (Mathiyazhagan et al., 2011).

Corrosion of different metals in biodiesel were also noticed (Sgroi et al., 2005; Tsuchiya et al., 2006; Geller et al., 2008; Maru et al., 2009; Haseeb et al., 2010). Kaul et al., (2007) investigated the corrosiveness of different biodiesel (Jatropha, Karanja, Mahua and Salvador). They found that biodiesel from Jatropha and Salvador were more corrosive for both ferrous and non-ferrous metal. Non-edible vegetable oils such as Jatropha and seed-bearing shrubs can provide an alternative and do not have competing food uses. However, these oils were characterized by their high free fatty acid contents. Conventional transesterification technique for the production of biodiesel is well established (El Sherbini et al., 2010).

Vegetable oils are also used as emergency fuels and other purposes during World War II. For example, Brazil prohibited the export of cottonseed oil in order to substitute it for imported diesel fuel (Sridharan and Mathai, 1974). China produced diesel fuel, lubricating oils, gasoline and kerosene, the latter two by a cracking process from tung and other vegetable oils (Williamson and Badr, 1998; Encinar et al., 2002). However, the exigencies of the war caused hasty installation of cracking plants based on fragmentary data (Encinar et al., 2002). Based on the usage of biodiesel during the World War II, more than ten vegetable oils were investigated for development of domestic fuel (Karaosmanoglu et al., 2000). Work on vegetable oils as diesel fuel was ceased in India when petroleum based diesel fuel became available again plentifully at low cost (Ma and Hanna, 1999). The Japanese battleship Yamato reportedly used edible refined soybean oil as bunker fuel (Zhou and Boocock, 2003).

In modern times, biodiesel has been reported to be producible from many different sources which include vegetable oils, animal fats, used frying oils and even soap stock. Generally, the geography of a country determines which vegetable oil is of most interest for biodiesel utilization. Thus, in the United States, soybean oil is considered as a prime feedstock, in Europe it is rapeseed oil (canola oil) and in countries with tropical climate it is palm oil. As alluded to above, different feed stocks were investigated in the historic times. These included palm oil, soybean oil, castor oil, and somewhat less common oils such as
babassu (Encinar et al., 2005) as well as non-vegetable sources such as industrial tallow (Karmee and Chadha, 2005) and even fish oils (Dorado et al., 2004; Ugheoke et al., 2007).

A blend of 20% bio-diesel fuel in diesel does not affect any of the measured performance (Agarwal, 2007; Murugesan et al., 2009). A 20% or less biodiesel blends or low level can be used as a direct substitute for diesel fuel in all heavy-duty diesel vehicles without any adjustment to the engine or fuel system (StanMcMillen et al., 2005; Rakopoulos et al., 2008; Agarwal et al., 2008). There are significant improvements observed in engine and emission characteristics for the biodiesel engine compared to diesel engine. Rakopoulos et al., (2008) have reported that the engine performance with the biodiesel blends of sunflower or cottonseed oil bio-diesels is similar to that of the neat diesel fuel with nearly the same brake thermal efficiency and showing higher brake specific fuel consumption. Narayana Reddy and Ramesh, (2006) have reported that there is an increase in the brake thermal efficiency in the case of Jatropha oil as compared to base diesel. The results from the detailed test conducted by Karthikeyan and Mahalakshmi, (2007) with turpentine–diesel engine are: increased specific fuel consumption (SFC) is reported at full load due to the presence of knock, maximum of 8% drop in volumetric efficiency is reported in diesel fuel engine at full load.

2.2 Review on the selected plant species

2.2.1 Neem (Azadirachta indica ADR. Juss)

2.2.1.1 Distribution

The neem tree is native to India and Burma. Neem tree is found abundance in tropical and semi-tropical regions, Sri Lanka, Pakistan, Tropical Australia and Africa (Meenadevi et al., 2008). It is native to India, Pakistan, and Bangladesh growing in tropical and semi-tropical regions. Neem trees also grow in islands in the southern part of Iran (Bhambal Ajay et al., 2011). Its fruits and seeds are the source of neem oil. It is estimated that India alone has a theoretical potential to produce 350,000 tons of oil per annum. Good quality kernels (50% by weight) yield 40% oil. In India, Neem oil has been found to yield 50% of the weight of kernel (Meenadevi et al., 2008).

2.2.1.2 Botany

Neem trees are fast growing, grow up to 35 m tall and evergreen, they lose their leaves during severe drought. The stem of a neem tree can grow up to a diameter of 2.5-3m. The bark is rough and pale or grayish black in color. They have wide spreading branches creating a scenic, round to oval crown that sits upon a relatively short trunk.
Neem tree bears small white colored flowers and star shaped with a pleasant smell (Kureel et al., 2009). One tree can produce millions of flowers and in one flowering cycle, a mature tree may produce many thousands of seeds. Neem tree generally bear fruits between the age of 3 to 5 and the fruits are edible. Seeds are small and round to oval in shape with oil content ranging from 20-33%, depending on the variety (Meenadevi et al., 2008). It is an ideal plant for indoors and requires least maintenance. Most of the problems relating to the growth of neem are due to over watering in case the neem leaves begin to turn yellow. It is a sign of over watering or that the tree has been given too much fertilizer in spite of biological ageing.

2.2.1.3 Phytochemistry

It is a revered tree in India with close to 150 compounds obtained from different parts of the tree. Neem is unusual in containing non-lipid associates often loosely termed as bittersand organic sulphur compounds that impart pungent and disagreeable odour. Neem seed contains the following compounds and they are 17 beta hydroxyl azadiradione, 17 epiazadiradione, 7 decacetyl 7 benzoyl azadiradine, 1- alpha methoxy 1,2 dihydro epoxyazadiradione, diepoxyazadiradione, 7 desercetyl 7 benzoyl epoxy azadiradione, 7 acetyl neo trichillinone, 7 diacetyl 7 benzoyl gedunin. Neem seed cake contain the compounds namely azadirachtin, nitrogen, phosphorous, potassium, carbon, sulphur, calcium and magnesium. Major fatty acid composition : Palmitic acid- 19.4%; Stearic acid- 21.2%; Oleic acid- 42.1%; Linoleic acid- 14.9%; Arachidic acid- 1.4% (Allameh et al., 2002; Ghorbanian et al., 2008; Meenadevi et al., 2008; Krishnan et al., 2012).

2.2.1.4 Medicinal uses

Neem trees are considered to be the sacred tree in India because of their multitudinous uses. Neem tree has been widely used in traditional system of medicine for centuries. Each part of Neem is used in medicines and thus commercially exploitable. Neem has been evaluated for safety and efficacy and it has been considered as a universal cure for diseases. It is considered to be a natural source for medicines and industrial products. Medicinal properties of neem compounds are as anti-inflammatory, antiarthritic, antipyretic, hypoglycemic, spermicidal, antifungal, antibacterial, diuretic, antimalarial and antitumor (Meenadevi et al., 2008). Neem bark acts as an analgesic and can cure fever. Neem flower is used to cure intestinal problems. Raw neem leaf and leaf extract can be used for reducing weight, skin diseases, ulcers and gastrointestinal problems. Bark is used for tanning due to its high tannin content. Neem twigs finds use as tooth brushes (Bhambal Ajay et al., 2011). The wood may be used for heating, construction and furniture and craft
Neem leaves are used for their insect repellent properties when crushed and mixed into a spray and they may also be used as a fertilizer.

Neem twig is used to cure common cold and cough, asthma and bronchitis, urinary tract disorders, diabetes and blood pressure (Rahman and Jairajpuri, 1993). Neem seed can be used to cure leprosy and other gastrointestinal problems. Neem oil is known to be effective against acne, eczema, psoriasis, other skin lesions, dandruff, lice, chicken pox, diaper rash, insect bites (Kureel et al., 2009). In India, neem oil extracted from the seeds is used for soap; the insecticidal and antifeedant property of neem oil is also used in medicine and as a natural pesticide, capable of repelling various harmful insects from food and fiber crops. Neem oil is known for its healing properties and is used in creams, lotions, insecticides and repellants (Bhaskara et al., 2010). Neem cake residue is used as organic manure resulting in high yield of crops and plants. Neem fertilizer is also in great demand as they are promising in controlling diseases such as white molds. Neem seed cake is a good pest repellent, organic fertilizer, acts as a biofertilizer and helps in providing the required nutrients to plants. It is widely used to ensure high yield of crops (Krishnan et al., 2012). Neem is used as a fertilizer both for food as well as cash crops, particularly vegetables and sugarcane. Neem leaves are used to manufacture organic and natural compost. It increases resistance to pest attacks and increases the nitrogen percentage in soil (Krishnan et al., 2011).

2.2.1.5 Neem as biodiesel

A lot of research work and experiments are being conducted worldwide to explore the viability of neem being used for biofuel production. This biofuel is marketed as blend with diesel (Anbumani and Singh, 2010). Neem trees are grown on commercial basis for their possible and effective use in manufacture of biodiesel. A blend of upto 20% of biofuel in diesel does not require much modification in automobile engines; also this biofuel will be cheaper than the regular fuel. Biofuel consumption is increasing in countries like Italy, US, Malaysia and Japan (Meenadevi et al., 2008). This poses a huge opportunity for countries like India and Burma, which are native places for neem tree. For transportation, it is a perfect substitute of conventional fuels used for lighting, fuel for trucks, buses, trains and diesel automobiles. Biofuel containing neem oil is used for rural electrification (Bringi, 1987).
2.2.2 Cotton (*Gossypium hirsutum* Linn.)

2.2.2.1 Distribution

Cotton is believed to have originated in Central America. Cotton was taken from Mexico to United States (*Wendel et al.*, 2009). During American civil war, it was introduced into most tropical and subtropical countries of the world. It is found in Africa, South America, South east Asia, India, Pakistan, the Philippine Islands, and cotton belt of the United States (*David and Falegan*, 2007).

2.2.2.2 Botany

Cotton is an annual subshrub grows up to 1.5 m tall. The branches are of two kinds: vegetative and fruiting. The leaves are alternate, petiolate, palmately 3-5 lobed, hirsute, blade cordate, as broad as long, 7.5-15 cm across; flowers are 6-8 on each fertile branch, large, white or yellow, subtended by a reduced calyx and 3-4 large green fringed bracts (*Burkill*, 1997; *Meenadevi et al.*, 2008); staminal column surrounding style made up of 100 or more stamens; superior ovary with 3-5 carpellate; fruit is a dehiscent capsule, 4-6 cm long, spherical, smooth, light green with few oil glands (*Gledhill*, 2008); seeds are 1 cm long, ovoid, dark brown, about 36 per fruit, bearing hairs of two kinds on the epidermis: long fibres called lint and short fibres strongly attached to the seed coat called fuzz; weight of 100 seeds will be 10-13 g with well developed taproot and with numerous laterals penetrating as deeply as 3 m (*Wendel et al.*, 2009).

2.2.2.3 Phytochemistry

One of the most important sources of commercial oils is cotton seed oil after it has been separated from the fibre. Cottonseed oil is a triglyceride derived from cotton. Cotton is a very important crop, has a protein, and fatty component, but unlike soybean, the fibre is useful in textile applications (*Kerkhoven and Mutsaers*, 2003). It contains 13% stearic, 21% (C_{15}H_{31}) palmitic, 32% (C_{17}H_{33}) oleic and 44% (C_{17}H_{31}) linoleic acids (*Neuwinger*, 2000; *Meenadevi et al.*, 2008). The best seed yields 20% or more of oil, which is largely used in the manufacture of soap, paints and refined qualities in salad oils. The supply of cottonseed is an important part of the industry in cotton-growing countries. Root bark contains 3% of a reddish acidic resin, a volatile oil, a phenolic acid (probably 2,3-dihydrobenzoic acid) salicylic acid, a colorless phenol, betaine, a fatty alcohol, a phytosterol (C_{27}H_{46}O), a hydrocarbon (probably triacontane), ceryl alcohol, and oleic and palmitic acid; also it contains isoquercitrin, quercimeritrin, quercetin-3’-glucoside, hirsutrin, isoastragalin, palmitic acid, oleic acid, linoleic acid, α- pinene, β- caryophyllene, bisabolol,
caryophylleneoxide, bisaboleno oxide, abscisin II, serotonin, chrysanthemin, gossypicyanin, and histamine (Smith and Cothren, 1999).

2.2.2.4 Economic uses of cotton

Commercial cottonseed contains approximately 92% dry matter, 16-20% protein, 18-24% oil, 30% carbohydrates, 22% crude fiber. After ginning, cottonseed includes unginned lint, fuzz, 16% crude oil, 45.5% cake or meal, 25.5% hulls, and 8% linters. Principal pigment in seed is gossypol, a poisonous phenolic compound usually rendered harmless on crushing or heating, but may retain minute amounts to which pigs and chickens are sensitive.

Cultivated primarily for its vegetable seed fiber, this species is considered the most important of the cotton yielding plants providing the bulk of commercial cottons. Fuzz, which is not removed in ginning, become linters in felts, upholstery, mattresses, twine, wicks, carpets, surgical cottons and in chemical industries such as rayons, film, shatterproof glass, plastics, sausage skins, lacquers and cellulose explosives (Ververis et al., 2004). Cottonseed and roots have been used in nasal polyps, uterine fibroids and other types of cancer. It has anticancer activity. Mucilaginous tea of fresh or roasted seeds is used for bronchitis, diarrhea, dysentery and hemorrhage. Flowers are diuretic and emollient used for hypochondriasis (Dowd, 2011). Leaves steeped in vinegar applied to the forehead for headache. Often used by early American slaves for abortion; apparently with no serious side effects.

Root decoction is used for asthma, diarrhea and dysentery. Root bark devoid of tannin, astringent, anti hemorrhoidal; used as an emmenagogue, hemostat, lactagogue, oxytocic, parturient and vasoconstrictor. Gossypol is used in China as a male contraceptive. Seeds yield a semi drying and edible oil, used in shortening, margarine, salad and cooking oils, and for protective coverings (Lukonge et al., 2007). Oil obtained from cotton seed is industrially used in a range of products, including margarine, mayonnaise, salad and cooking oils, and for protective coverings (Lukonge et al., 2007). Oil obtained from cotton seed is industrially used in a range of products, including margarine, mayonnaise, salad and cooking oils, and for protective coverings (Lukonge et al., 2007). Oil obtained from cotton seed is industrially used in a range of products, including margarine, mayonnaise, salad and cooking oils, and for protective coverings (Lukonge et al., 2007). Oil obtained from cotton seed is industrially used in a range of products, including margarine, mayonnaise, salad and cooking oils, and for protective coverings. Locally it serves for cooking and frying. The oil could be used as a biofuel. Residue, cottonseed cake or meal is important protein concentrate for livestock. The bread made with cottonseed protein is an even better source of protein than enriched white bread, six slices of which provide 20% of the adult RDA. Low-grade residue serves as manure, bedding and fuel (Lopes and Steidle, 2011).
2.2.2.5 Cotton as biodiesel

The most commonly used oils for the production of biodiesel are soybean, sunflower, palm, rapeseed, canola, cottonseed (Kose et al., 2002) and Jatropha. The cotton plant is one of the most important raw materials of textile industry for fibers, food and feed industry due to its 17-24% oil and 40-43% protein contents (Incekara, 1979). Turkey has about 760,000 ha of area under cotton, 882,000 tonnes of cotton fiber production per annum with a yield of 1160 kg/ha of lint cotton and therefore is one of the foremost cotton producing countries of the world (RTMARA, 1998). The residue oil cake is also used as biofertilizer and cattle feed supplement. The fatty acid composition of the cotton seed oil is palmitic, stearic, oleic and linoleic acids (Goering et al., 1982). Biodiesel is generally produced from different sources of plant oils such as cottonseed oil (Kose et al., 2002; He et al., 2007; Royon et al., 2007; Azcan and Danisman, 2007; Rashid et al., 2009; Hoda, 2010).

Blends of cotton-oil biodiesel and diesel fuel can be used in conventional diesel engines without any major changes (Sivakumar et al., 2009). The seed cake remaining after oil extraction is an important protein concentrate for livestock. Low-grade cake is used as manure. The whole seed can be fed to ruminants, which are less sensitive to the toxic gossypol in the seed than non-ruminants or is applied as manure. Hulls are low-grade roughage for livestock or serve as bedding or fuel. Leftover bolls, leaves and thin twigs are grazed by ruminants. Dry stalks serve as household fuel (Ranganathan et al., 2011).

2.2.3 Castor (Ricinus communis Linn.)

2.2.3.1 Distribution

*Ricinus communis* Linn.is popularly known as castor bean plant and is native to tropical Africa. It is cultivated in all warm countries, more particularly in India, Asia, Europe, United States, Illinois, Missouri, Kansas, Oklahoma, Oregon, California and the warmer Mediterranean countries – Algeria, Egypt, Greece and the Riviera (Christopher Brickell, 1996).

2.2.3.2 Botany

A tall, quick-growing perennial, woody shrub or small tree, rarely more than 4 to 5 feet height with thick, hollow, herbaceous stems which are cylindrical, smooth and shiny with a purplish bloom in the upper part with large handsome palmate-peltate leaves placed alternately on the stem on long curved purplish foot-stalks with drooping blades, generally 6-8 inches across, sometimes still larger, palmately cut for three-fourths of their depth into
seven to eleven lance-shaped, pointed, coarsely toothed segments (Meenadevi et al., 2008). When fully expanded, they are of a blue-green colour, paler beneath and smooth; when young, they are red and shining. Their colour varies from dark green, sometimes with a reddish tinge to dark reddish purple or bronze. The stems and the spherical spiny seed pods also vary in pigmentation.

The flowers are green and inconspicuous, but pink or red in the pigmented varieties. The flowers are male and female on the same plant and are produced on a clustered, oblong, terminal spike (Christopher Brickell, 1996). The male flowers are placed on the under portion of the spike; they have no corolla, only a green calyx, deeply cut into three-five segments, enclosing numerous, much branched yellow stamens. Many stamens are near the base and branching pistils are nearly at the top of the flower. The female flowers occupy the upper part of the spike. The three narrow segments of the calyx are reddish in colour and their ovary in their center is crowned by deeply divided, carmine-red threads (styles). The pods are showier than the flowers (the male flowers are yellowish-green with prominent creamy stamens and are carried in ovoid spikes upto 15 cm long; the female flowers are born at the tips of the spikes, have prominent red stigmas).

The fruit is a blunt, greenish, deeply-grooved capsule less than an inch long, covered with soft, yielding prickles in each of which a seed is developed. Seeds are oval and light brown, mottled and streaked with light and dark brown and resemble a pinto bean. The fruit consists of an oblong, spiny pod which contains three seeds on average. The soft spined fruits containing attractively mottled seeds are distinctive features of the plant (Williamson 2002). The seeds of the different cultivated varieties differ much in size and in external markings but average seeds are of an oval, laterally compressed form. The smaller annual varieties yield small seeds- the tree forms larger seeds. They have a shining marble-grey and brown, thick, leathery outer coat, within which is a thin, dark-coloured, brittle coat (Roger and Rix, 1999). A large distinct, leaf embryo lies in the middle of a dense, oily tissue (endosperm). It is grown as an ornamental in gardens, sometimes as a houseplant, and also grows as weed.

### 2.2.3.3 Phytochemistry and medicinal properties

Castor seed is the source of castor oil which has a wide variety of uses. The seeds contain between 40% to 60% oil that is rich in triglycerides, mainly ricinolein. They contain ricin, a poison, which is also present in lower concentrations throughout the plant (Srivastava et al., 2014). Castor oil consists of 90% unsaturated C:18 ricinoleic fatty acid. It is a major source of sebacic acid. It contains ricinoleic 90%, linoleic 3-4% and oleic 3-4%
(Zahir et al., 2010). The seeds contain 50% of the fixed oil which is a viscid fluid, almost colorless when pure, possessing only a slight odor and mild, yet highly nauseous and disagreeable taste. Its specific gravity is high for oil being 0.96 g/ml, a little less than that of water, and dissolves freely in alcohol, ether and glacial acetic acid. It contains palmitic and several other fatty acids, among which there is one – ricinoleic acid, peculiar to itself. This occurs in combination with glycerine, constituting the greater part of the bulk of the oil. The oil is decomposed by the fat-splitting ferments of the intestinal canal liberating this irritant ricinoleic acid (Wedin et al., 1986). Castor beans are pressed to extract the castor oil which is used for medicinal purposes. Ricin does not partition into the oil because it is water-soluble, therefore, castor oil does not contain ricin, provided that no cross-contamination occurred during its production.

Seeds and the cake left after the expressions of the oil are violently purgative, a property which is due to the presence of the highly toxic albumin ricin, which exhibits its highest toxicity when injected into the blood (Soto-Blanco et al., 2002). By injecting gradually increasing doses, immunity was established, a condition which attributed to the formation of an antibody termed antiricin. The seeds from castor bean plant are poisonous to people, animals and insects. One of the main toxic proteins is ricin. The agglutination was due to another toxin that was also present, called RCA (Ricinus communis agglutinin). Ricin is a potent cytotoxin but a weak hemagglutinin (Meenadevi et al., 2008), whereas RCA is a weak cytotoxin and powerful hemagglutinin. Poisoning by ingestion of the castor bean is due to ricin, not RCA, because RCA does not penetrate the intestinal wall, and does not affect the red blood cells unless given intravenously. If RCA is injected into the blood, it will cause the red blood cells to agglutinate and burst by hemolysis. One milligram of ricin can kill an adult (Tan et al., 2009). If the seed is swallowed without chewing, and there is no damage to the seedcoat, it will most likely pass harmlessly through the digestive tract. However if it is chewed or broken and then swallowed, the ricin toxin will be absorbed by the intestines.

Castor oil differs from the conventional soap making oils in that the oil contains glyceride of ricinoleic acid, which has in its chemical structure a hydroxyl group, which confers undesirable properties from the point of view of using the oil in soap making, e.g. ease of salting out the soap from the saponification mass. It is therefore necessary to modify the oil by a process of dehydroxylation (Lomash et al., 2010). Even after dehydroxylation, the oil gives rise to a soft soap. Therefore, a hydrogenation step is also necessary. The procedure that is adopted on a commercial scale is to hydrogenate the oil to an iodine value of less than 5, under controlled conditions to minimize the formation of keto-stearic,
conjugated dienoic acid, estolides and elaidic acids (Zahir et al., 2010). The oil is dehydroxylated using acid activated earth under vacuum. The resultant oil may be termed as castor olein since the bulk of the ricinoleic acid in the oil is converted during the hydrogenation dehydroxylation step to oleic acid. The processed castor oil can be used to the extent of 30-40% in laundry soaps and up to 30% in toilet soaps. However, processed castor oil is more expensive as compared to processed ricebran oil and hence its usage is generally restricted to toilet soaps. The oil contains a small proportion of hydroxy and kete-stearic acids. Uncontrolled levels of these constituents can lead to difficulties in plodding of the soap, since the soap undergoes the process termed as “work softening” due to mechanical working in the plodder. Extrusion of bars becomes difficult.

Castor oil is regarded as one of the most valuable laxatives in medicine. The use of castor seed oil in India has been documented since 2000 BC for use in lamps and in local medicine as a laxative, purgative and cathartic in unani, ayurvedic and other ethnomedical systems (Joshi et al., 2004). It is used for temporary constipation and wherever a mild action is essential. It is extremely useful for children and the aged. It is used in cases of colic and acute diarrhea due to slow digestion but must not be employed in cases of chronic constipation (Williamson, 2002). It acts in about five hours, affecting the entire length of the bowel, but not increasing the flow of bile, except in very large doses (Meenadevi et al., 2008). It is also used for expelling worms, after other remedies have been administered. The oil will purge when rubbed into the skin or injected (Lomash et al., 2010). The only serious objections to the use of castor oil are its flavour and the thickness often produced by it. The nauseous taste may be disguised by administering with lemon oil, sassafras oil and other essential oils or floating on peppermint or cinnamon water or coffee, or shaken up with glycerine or given in fresh or warm milk (Kalaiselvi et al., 2003).

Castor oil forms a clean light-colored soap, which dries, hardens well and is free from smell. The inferior qualities of the oil are frequently employed in India for soap-making. It may also be made into an emulsion with the yolk of an egg or mucilage; or with orange-wine or gin. Externally, the oil has been recommended for various cutaneous complaints, such as ringworm and itch (Zahir et al., 2010). The fresh castor oil is an excellent solvent of pure alkaloids such as atropine, cocaine which are used in ophthalmic surgery. It is also dropped into the eye to remove the irritation caused by the removal of foreign bodies. About 1% of the global castor oil production goes into medical or health store products. The principal toxin of castor bean is ricin which is a lectin, also termed a toxalbumin (Irwin, 1982). Ricin may comprise upto 3% of the seed weight. Toxalbumins are very toxic plant-derived compounds that combine carbohydrate and protein (Oyewole
et al., 2010). Ricin is water soluble and is not present in castor oil. Oral application of ricin is readily absorbed from the stomach and intestine. Another phytotoxin in castor bean is ricinine, reportedly goitrogenic (Sabina et al., 2009).

The valuable purgative known as castor oil is the fixed oil obtained from the seeds of the castor oil plant. The oil on account of its cheapness and abundance is extensively employed for illuminating as well as other domestic purposes. Castor oil and its derivatives have major application in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, leather dressing, coatings, inks, cold resistant plastics, waxes, polishes, nylon, pharmaceuticals and perfumes (Kalaiselvi et al., 2003). The poison ricin is made from the by products in the manufacture of castor oil. It is largely used in the manufacture of artificial leather and in upholstery. It is an essential component in some waterproof preparations and one of the largest uses in the manufacture of transparent soaps. The residue (castor cake) after the expression of oil is valuable manure but it is unfit for cattle-food; it is largely used for crops in the tropics. The seed as well as the cake contain an alkaloid poison (ricin), which however does not pass into the oil. The leaves furnish the principal food of silk-worm. Castor oil is used as an emollient and skin softener, as well as for other skin problems such as psoriasis (Sabina et al., 2009). Castor oil is also used in the manufacture of fiber optics, bulletproof glass and bone prostheses. And it is indispensable for preventing fuels and lubricants utilized in aircrafts and space rockets from freezing at extremely low temperatures.

2.2.3.4 Castor as biodiesel

The castor oil plant is found to be a best source for the production of biodiesel. In search for more ecofriendly fuels, the use of castor oil has proven to have technical and ecological benefits and stands as an opportunity for agricultural development in arid zones. The oil extracted from castor bean already has a growing international market, assured by more than 700 uses, ranging from medicines and cosmetics, and replacing petroleum (Meenadevi et al., 2008). European and US farmers have created national and international associations to promote Castor as an alternative fuel, which reduces urban air pollution and emissions of green house gases associated with the burning of fossil fuels (Mohibbe Azam et al., 2005). Castor oil is the best substance for producing biodiesel because it is readily soluble in alcohol and does not require heat and the consequent energy requirement like other vegetable oils in transforming them into fuel (Katwal and Soni, 2003). Castor oil will be competitive with other vegetable oils in energy market. The castor oil plant is easy to grow and resistant to drought, which makes it an ideal crop for the extensive semi arid region.
2.2.4 Gingelly (*Sesamum indicum* Linn.)

2.2.4.1 Distribution

*Sesamum* is believed to be originated in Asia and widely distributed in Ceylon, South India, Africa, Europe, Egypt, Middle East and Asia, North America, China, Sudan, Myanmar, and Mexico (Ram *et al.*, 1990).

2.2.4.2 Botany

It is an annual plant growing to 50 to 100 cm tall, with ovate, opposite leaves 4 to 14 cm long, deeply veined with an entire margin. They are broad, lanceolate, to 5 cm broad, at the base of the plant, narrowing to just 1 cm broad on the flowering stem (Bedigian, 1988). The flowers are white to purple, shaped like a trumpet on short peduncles in axils of leaves, 3 to 5 cm long, with a four-lobed mouth, mature into pods containing the edible sesame seeds. One to three flowers appear in the leaf axils (Bedigian, 1984). The fruit are about 2.5 cm long, is an oblong capsule with small seeds. Each plant has 15-20 fruits, which contain 70-100 seeds each. Plants and fruit will reach maturity in 80-100 days after sowing. When the seeds are ripe, the capsule bursts open suddenly and scatters its seeds.

2.2.4.3 Phytochemistry

The chemical constituents including sesamin (*C*<sub>20</sub>*H*<sub>18</sub>*O*<sub>6</sub>) 0.18%~0.21%, sesamolin (*C*<sub>20</sub>*H*<sub>18</sub>*O*<sub>7</sub>), sesamol, vitamin E, lecithin (0.65%), phytosterol, sesame lectin, planteose, sesamose, cytochrome C, nicotinic acid (0.48mg%), folic acid (18.45mg%), sucrose (0.64%), and protein (22%) namely alpha-globulin, beta-globulin, 13s-globulin, albumin, glutelin and pedalin are present (Meenadevi *et al.*, 2008). Both sesamin and sesamolin belong to a group of special beneficial fibers called lignans and have been shown to have a cholesterol-lowering effect in humans and to prevent high blood pressure and increase vitamin E supplies in animals. Sesamin has also been found to protect the liver from oxidative damage (Kamal-Eldin *et al.*, 2011). Phytosterols are compounds found in plants that have a chemical structure very similar to cholesterol and when present in diet in sufficient amounts, are believed to reduce blood levels of cholesterol, enhance the immune response and decrease risk of certain cancers.

Sesame oil is polyunsaturated and high in oleic and linoleic fatty acids that are rich in omega 6. Sesame oil is mostly composed of triglycerides of the singly unsaturated oleic acid (40%) and the doubly unsaturated linoleic acid (45%), besides approximately 10% fats (iodine index 110). The chief constituent of the sesame seed is its fatty acid which usually
amounts to 44-60%, noted for its stability, the oil resists oxidative rancidity (Cheung et al., 2007). The excellent stability is due to the presence of natural antioxidants such as sesamolin, sesamine and sesamol. The fatty acid composition of sesame oil is oleic acid (45%), linoleic acid (37%), palmitic acid, stearic acid, linolenic acid, sinnapic acid and arachidic acid. It also contains fat mainly loneleic acid, sucrose, lecithin, protein, including vitamins A, D and E. Black sesame seed is extremely rich in calcium, containing 85 milligrams per gram of seeds, high in protein, phosphorous, iron and magnesium also a good source of vitamin B1, zinc and dietary fiber.

2.2.4.4 Economic uses

Sesame is used to tonify the liver, kidney, spleen, large intestine channels. Black sesame seed is a good tonic herb. In addition to its essence-building capacity, black sesame also builds blood (Ogasawara et al., 1998). Black sesame seed is moistening to the intestines and helps move the bowels. It prevents and relieves constipation due to dryness of the intestines. Black sesame blackens the hair. Hence it is applied to white hair, habitual constipation, and insufficient lactation. Sesame oil is also helpful in treating intestinal worms like ascaris, tapeworm, etc. Black sesame rich in vitamin E which prompts the mature growth of ovary, increase amount of mature oocyte, stimulate the secretion of estrogen, thus enlarge the galactophore, canal growth and enlarge breast size. Antioxidant from sesame releases a strong anti aging effects (Ivon et al., 2005).

Sesame has a high magnesium content to help steady nerves and is used in laxatives as an emollient. One half cup of sesame seeds contains over three times the calcium of a comparable measure of whole milk (Permaul et al., 2009). Sesamin, a lignan found only in sesame seeds, has remarkable antioxidant effect which can inhibit the absorption of cholesterol and the production of cholesterol in the liver. Sesame seeds have a nutty, slightly sweet flavor and aroma which is enhanced by toasting. Sesame oil is remarkably stable and will keep for years without turning rancid even in hot climates. The seeds come in a variety of colors depending on the plant variety, including shades of brown, red, black, yellow and most commonly a pale grayish ivory (Aaronov et al., 2008). The darker seeds are said to be more flavorful, but beware of seeds that have been dyed. Black and golden sesame seeds are the un-hulled seeds which may be either black or golden brown. White sesame seeds are hulled seeds and are the most popular type to use in cooking. When baked or toasted, sesame seeds acquire a delicious nutty, crunchy taste which makes them popular on biscuits and breads and even sprinkled over ice cream instead of chopped nuts. Roasted or unroasted sesame seeds can be used for a variety of culinary dishes, rolls, meats, pastas,
and vegetables. Seed pastes are used in sauces for coating and dipping (Meenadevi et al., 2008).

*Sesamum* has a delicious flavor and aroma. It contains lecithin and phosphorous lipids which are highly recommended for sportsman and people with stress (Ben-Shoshan et al., 2010). The oil aids in mental and physical recovery. It is recommended for all type of food preparation from delicious salads, stir fries, manufacture of margarines all other healthful and nutritious foods, manufacture of soaps, pharmaceuticals, lighting, lubricants, cosmetics and as a base in developing perfumes. The oil has remarkable cosmetic properties, being very rich in essential fatty acids, vitamin E and it acts as an anti-free radical, moisturizes, nourishes and regenerates (Cheung et al., 2007).

Sesame oil is used in the preparation of Iodinol and Bominol, which are employed for external, internal or subcutaneous use. Used liberally in Chinese cooking, sesame oil is added to many dishes as a seasoning just before serving to benefit fully from its unique fragrance. Chinese confectioners have long flavored the use of sesame seeds as a coating on their deep-fried sweets, still available in oriental bakeries today (Kamal-Eldin et al., 2011). The oil is used as a fuel. The oilcakes left after pressing sesame oil are rich in protein and are used as cattle feed and as a subsistence for food. It contains 35-50% protein, and is rich in tryptophan and methionine. Seed cake is used as animal feed, while the remainder is ground into sesame flour and added to health foods.

**2.2.4.5 Sesamum as biodiesel**

Banapurmath et al., (2008) reported the use of Sesame blend as biodiesel in a single-cylinder, four-stroke, direct-injection, CI engine. A blend of 50% sesame oil and 50% diesel fuel was used as an alternative fuel in a direct injection diesel engine and the engine power and torque of the mixture of sesame oil–diesel fuel are close to the values obtained from diesel fuel and the amounts of exhaust emissions are lower than those of diesel fuel. Hence, it is seen that blend of sesame oil and diesel fuel can be used as an alternative fuel successfully in a diesel engine without any modification and also it is an environmental friendly fuel in terms of emission parameters (Altun et al., 2008; Hosmath and Mohanan 2009). Several studies investigated the use of sesame seed as an alternative feedstock for the production of biofuel and the results supported that its methyl ester can be successfully used as diesel (Saydut et al., 2008; Panoutsou et al., 2008).
2.2.5 Mustard (*Brassica juncea* Linn.)

2.2.5.1 Distribution

Mustard is a native of Europe, and found in Greece, England, South Siberia, Asia, Africa, America, Holland, Italy and Germany (Spect and Diederichsen, 2001).

2.2.5.2 Botany

Mustard is an erect annual plant grows about a foot or more in height, with pinnatified leaves, large, yellow and cruciferous flowers. The fruits of the two plants (white and black mustard) differ considerably in shape. The black mustard pods are erect and smooth. Each pod contains four to six globular seeds about 1/12 inches in diameter, yellow both on the surface and internally (Barcikowska et al., 1994). The seed-coat though appearing smooth, on examination with lens, is seen to be covered with minute pits and to be finely reticulated (Hemingway, 1976). The inner seed coats contain a quantity of mucilage. The cotyledons of the seeds contain oil and give a pungent but inodorous emulsion with water (Bibbey, 1948).

The epidermal cells of the seed coat of white mustard seeds contain mucilage. The cotyledons contain 31-33% fixed oil, which consists of the glycerides of oleic, stearic and erucic or brassic acids and behenic acids (Baranger et al., 1995). The seed contains the crystalline glucoside sinalbin and the enzyme myrosin which unite to form a volatile oil, called sinalbin mustard oil, used for various purposes, though not so pungent as that of black mustard (Getinet et al., 1997; Wilkes et al., 2013). This oil cannot be obtained by distillation but is extracted by boiling alcohol after the seed has been deprived of the fixed oil. When cold the volatile oil possesses only a faint, anise-like odour, but a pungent odour is given off on heating (Eber et al., 1994). The cake after the oil is expressed, is pungent and therefore not well fitted for cattle food but is used as manure.

2.2.5.3 Medicinal properties

Mustard is used from very early times. Hippocrates advised their use both internally and as a counter irritating poultice, made with vinegar. Mustard is administered frequently in disorders of the digestive organs (Prakash, 1980). White mustard seeds were used as a laxative, especially for old people, but from their danger of their retention in the intestines. They are not very safe in large quantities having in several cases caused inflammation of the stomach and intestinal canal. The dried, ripe seeds are commonly used in medicines. They possess rubefacient properties and are mixed with black mustard seeds to produce mustard flour for preparing mustard poultices. The powder is not frequently adulterated.
with farinaceous substances, colored by turmeric. The seeds are ground to form a pungent powder, but it is much inferior in strength to that of black seeded species. An infusion of the seeds will relieve chronic bronchitis, confirmed rheumatism and for a relaxed sore throat (Warwick and Francis, 2005).

Mustard seeds act as an irritant, stimulant, diuretic and emetic. Mustard is used in the form of poultices for external application near the seat of inward inflammation, chiefly in pneumonia, bronchitis and other diseases of the respiratory organs. It receives congestion of various organs by drawing the blood to the surface (Singh et al., 1997). Oil of mustard is a powerful irritant and rubefacient and when applied in the skin in its pure state, it produces almost instant vesication but when dissolved in rectified spirit or spirit of camphor or employed in the form the compound liniment of mustard, it is a very useful application for chilblains, chronic rheumatism and colic (Salisbury, 1989). The bland oil expressed from the hulls of the seeds, after the flour has been shifted away, promotes the growth of the hair and may be used with the benefit externally for rheumatism.

White and black mustard are wild herbs growing in waste lands in India, but are cultivated commercially for their seeds which are valuable medicines. Both mustards afford excellent fodder for sheep. The white mustard is more frequently used since it is less pungent though equally nutritious (Hemingway, 1995). White mustard makes a good catch crop, being ready for consumption for the sheep eight or nine weeks after being sown. The green manure helps to prevent the waste of nitrates which instead of being washed away in drainage water (Katiyar and Chamola, 1995). The seeds of the mustards retain their vitality for a great length of time when buried in the ground.

2.2.5.4 Mustard as biodiesel

Anbumani and Singh (2010) reported that mustard oil at 20% blend with diesel gave best performance in CI engine in terms of low smoke intensity, emission of HC and NOx. Further esterified mustard oil at 20% blend satisfied the important fuel properties as per the ASTM (American Society for Testing and Materials) specifications for biodiesel as it lead to an improvement in engine performance and emission characteristics without bringing any modifications in the engine. Trethowan et al., (2009) evaluated the potential use of Indian mustard as a source of renewable oil for biodiesel production in New South Wales. Kirk and Oram (1978) analysed the use of mustard oil in Australia. Ravichandran et al., (2008) evaluated the oil for biofuel production and estimated glucosinolate levels of mustard cake. Jham et al., (2009) reported wild mustard oil as a feedstock for biodiesel production.
2.3 Review of research work on biodiesel properties of selected plants

2.3.1 Neem

The fuel properties of neem biodiesel were within the limits and comparable with the conventional diesel. Except calorific value, all other fuel properties of neem biodiesel were found to be higher as compared to diesel (Meda Chandrasekar et al., 2009). Energy life cycle of the biodiesel starts with the extraction of raw material. Life cycle analysis shows the inputs of extra energy needs to convert the energy present in the raw material into useable energy of the fuel. The life cycle analysis calculates the net energy ratio which is evaluated by dividing the energy output of the system in the form of fuel energy delivered to the compression ignition engine by the cumulative energy demand of the system. Yadav et al., (2010) analyzed biodiesel production and identified resource consumption and energy use for neem biodiesel in compression ignition engines.

Anbumani and Singh (2010) used the non-edible neem oil as diesel substitute for CI engine and noticed that a 20% blend gave closer performance to pure diesel. The technical feasibility of using neem oil methyl esters gave much better results comparable to pure diesel (Kaufman and Ziejewski, 1984; Silva et al., 2003; Raheman and Phadatare, 2004). Rao et al., (1980) investigated the utility of neem methyl esters and compared with *Pongamia* and *Jatropha* methyl esters as biodiesel on CI engine. They observed better results with neem methyl esters. Gopinath et al., (2010) investigated the potentiality of neem oil and its blends as biofuel and compared them with other biofuels. The test engine used was a single cylinder four-stroke air-cooled diesel engine. Results indicated that biodiesel of neem with a higher peak pressure value correlated with maximum heat release and lower percentage of unsaturation when compared to other biofuels.

Singh and Singh (2010) had reviewed the Characterization of neem oil for biodiesel production as a substitute of diesel. Banapurmath et al., (2008) conducted a study on dual fuel using neem and rice bran oils and noticed that the brake thermal efficiency was improved marginally when the injection timing was advanced. They reported decreased smoke and NOx emissions during dual fuel mode compared to single fuel operation. Mathiyazhagan et al., (2011) reported the solution for food oil crisis by using cheapest low cost non-edible oils such as neem for biodiesel production. Srivastava and Prasad (2000) analysed the chemical composition of *Azadirachta* in order to produce triglyceride based biofuel. Naga Prasad (2010) tested neem, karanja, simuruba, cottonseed, *Jatropha* and *Pongamia* oil and their blends with diesel on a 4 stroke, single cylinder diesel engine and reported that smoke, CO, and Un-burnt hydrocarbons are more than those of diesel for blends.
2.3.2 Cotton

Kose et al., (2002) demonstrated the use of cottonseed oil in a solvent free medium for the production of biodiesel. Joshi et al., (2008) optimized cotton seed oil to produce biodiesel high in gossypol content. Sivakumar et al., (2009) compared the performance and emissions of diesel engine from neat and transesterified cotton seed oil. Ranganathan et al., (2011) analysed the performance and combustion of direct injection diesel engine using cotton seed oil. Caglayan et al., (2005) reported that unique minor components of cotton seed oil such as natural anti-oxidants gossypol and carotene may play important role in retarding the oil oxidation. It was also reported that cottonseed oil itself could be a cost-effective component in the formulation to achieve a significant improvement in combustion efficiency, increasing cetane number and reduction in exhaust in terms of CO, NOX and PM (Fan et al., 2008).

In spite of the multipurpose usage of cottonseed oil in shortening, margarine, protective coverings, salad and cooking oils, it also finds a remarkable application as a Biofuel (Meenadevi et al., 2008). The enzymatic transesterification of cottonseed oil was studied by Royon et al., (2007) using immobilized Candida antarctica lipase as catalyst in t-butanol solvent. Dindorkar et al., (2008) evaluated the cottonseed oil for biodiesel production and they observed that methyl ester of cottonseed oil satisfied ASTM specifications and can be used as a potentially functional substitute for diesel fuel in a CI engine. Simoni et al., (2006) have studied the ethanolysis of cotton seed oil using classical catalysts for biodiesel production. Bikou et al., (1999) analysed the effect of water on the transesterification kinetics of cottonseed oil with ethanol for efficient biofuel production.

Nagarhalli et al., (2009) investigated the performance and emission characteristics of blended (20-60%), neat cotton seed oil biodiesel and baseline diesel and reported that the thermal efficiency, brake specific energy consumption exhaust gas temperature were minimum for 20% blend of biodiesel. Rashid et al., (2009) evaluated the properties of biodiesel obtained from cottonseed oil and found it close to the properties of commercial diesel. Azcan and Danisman (2007) produced biofuel from alkali catalyzed transesterified cottonseed oil by microwave irradiation. The work by Qian et al., (2008) and Shu et al., (2009) illustrated the potential of biodiesel produced from cottonseed oil. Hariharan et al., (2009) conducted the performance of the cottonseed oil fuelled engine in comparison with diesel fuelled engine. It was reported that the cottonseed oil can be used without any difficulty either in esterified form or in refined form. Heat loss in the engine was reduced by the usage of cottonseed oil.
Keskin et al., (2008) studied the usability of cotton oil soapstock biodiesel–diesel fuel blends as an alternative fuel for diesel engines and tested in a single cylinder DI diesel engine. Engine performances and smoke value were measured at full load condition. Torque and power output of the engine with cotton oil soapstock biodiesel–diesel fuel blends decreased by 5.8% and 6.2%, respectively. Specific fuel consumption of engine with cotton oil soapstock–diesel fuel blends increased up to 10.5%. At maximum torque speeds, smoke level of engine with blend fuels decreased up to 46.6%, depending on the amount of biodiesel. Rakopoulos et al., (2008) reported that the engine performance with the biodiesel blends of sunflower or cottonseed oil bio-diesels is similar to that of the neat diesel fuel, with nearly the same brake thermal efficiency and showing higher brake specific fuel consumption.

2.3.3 Castor

Melis (1924) proved experimentally the successful transformation of castor oil into light fuels. Oliveira et al., (2005) optimized the production of biodiesel using castor oil and soybean oil. Goodrum and Geller (2005) evaluated the influence of fattyacid methyl esters from castoroil on diesel lubricity. Vidosh et al., (2011) reported the utility of nonedible esters in the field of biofuel production. He also added that blends are the most feasible way for enhancing the bio-diesel share on the fuel market, giving an appropriate income to farmers, competitive prices to end-users and requiring less taxation incentives and exemptions. Lamers (2010) used castor oil as a feedstock for commercial biodiesel production. Srivastava and Prasad (2000) investigated the utility of triglyceride-based diesel fuels with castor oil. It was reported that castorseed serves one of the best sources of feedstock for biofuel production (Puhan et al., 2008).

Castor oil is reported to be a potential biofuel in the United Nations Conference on Trade and Development in the year 2006. Mukunda (1999) used castor oil as one of the feedstock for biodiesel production in order to enhance the energy security. Demirbas (2003) surveyed the fatty acid composition of castor seed oil and channelized it for biodiesel production using transesterification methods. Castor oil is less expensive than edible oils and could be available to produce biodiesel (Barnwal and Sharma, 2005). Scholz and Silva (2008) reviewed the utility of castor oil as a fuel. Sousa et al., (2010) studied the acid value and neutralization of castor oil with glycerol in biodiesel production. Varma and Madras, (2007) produced biodiesel from castor and linseed oils with Novozym 435, a microalgae.
Yuan et al., (2009) surveyed the biodiesel production by using microwave assisted method from castor oil. Transesterification of castor oil for biofuel production assisted by microwave irradiation technique was carried out by Perin et al., (2008). Castor oils comprise 90 to 98% triglycerides and small amounts of mono- and diglycerides. These contain substantial amounts of oxygen in its structure and it can be used as an alternate for commercial diesel (Srivastava and Prasad, 2000). Ilieff (1939) used alcohol (ethanol) for improving the atomization and combustion of highly viscous castor oil. Biodiesel obtained from castor oil has a low cost compared to the ones obtained from other oils due to its solvability in alcohol (Conceicao et al., 2007). The biodiesel produced from castor bean also satisfies the relevant quality standards (Jeong and Park, 1996).

2.3.4 Gingelly

Saydut et al., (2008) investigated sesame seed oil as an alternative feedstock for the production of biofuel and their results supported that its methyl ester can be successfully used as a diesel. Sesame seeds are cultivated mainly for use in oil production (Carvalho et al., 2001). Seagri (2010) supported the fact that methyl esters of *Sesamum indicum* L. can be used as a potential biodiesel. Banapurmath et al., (2008) conducted the experimental analysis on a single cylinder, four stroke, and direct injection CI engine operated with sesame oil methyl esters. Engine performance in terms of higher brake thermal efficiency and lower emissions (HC, CO, NOₓ) with sesame oil methyl ester operation was observed. Rajashekar et al., (2012) have reported that B20 blend was found to be the best blend with regard to performance and emission characteristics compared to all blends when bio diesel from sesame oil is used.

Varma et al., (2010) produced biodiesel from sesame oil using microalgae as a catalyst. Brar (1982) studied the variation and correlation in oil content and fatty acid composition of sesame for biodiesel production. Srivastava and Prasad (2000) analysed the fuel properties of biodiesel obtained from *Sesamum indicum*. Knothe et al., (1996) summarized the fuel properties of sesame oil for its utility as a biofuel. NREL (2009) reported that sesame oil can also be used as a biodiesel. Demirbas (2003) synthesized biodiesel fuel via catalytic and non-catalytic supercritical alcohol transesterification of sesame oil. Haas (2005) improved the economics of biodiesel production through the use of sesame oil as feedstock. Altun et al., (2008) investigated the engine performance and exhaust emissions of 50% blend of sesame oil in a DI diesel engine. They observed that the engine power and torque of the blend was close to the values obtained from diesel fuel and the amount of exhaust emissions are lower than those of diesel fuel. Razon (2009) described the utility of *Sesamum indicum* as a second generation energy crop for the

2.3.5 Mustard

Varma et al., (2010) produced biodiesel from mustard oil using micro algae with different acyl acceptors as a catalyst and their results showed conversion of 70% and 65% using methanol and ethanol respectively. Sinha et al., (2007) reported that the metabolic engineering of fattyacid biosynthesis in *Brassica juncea* has improved the nutritional quality of seed oil. George et al., (2006) evaluated the oil content and fatty acid composition of mustard. Jham et al., (2009) studied the fuel properties of *Brassica juncea* seed oil methyl esters and summarized that mustard oil appears to be an acceptable feedstock for biodiesel production. Anbumani and Singh (2010) carried out the engine efficiency studies using 20% mustard oil blends and observed best performance in terms of low smoke intensity, emission of HC and NOx. Saka et al., (2010) utilized mustard oil for biodiesel production in supercritical conditions using microwave and ultrasound techniques.

Ozcimen and Yucel (2010) produced biodiesel from cheaper raw materials such as mustard oil. Yucel et al., (2010) evaluated the production of biodiesel from mustard oil along with waste frying oil by microwave method. Bouaid et al., (2005) carried out pilot plant study using *Brassica* as raw material for biodiesel production. Cardone et al., (2002) utilized mustard as an alternative oil crop for the production of biodiesel in Italy. They also characterized mustard oil and evaluated agronomically for biodiesel production (Woods et al., 1991; Cardone et al., 2003; Ozcimen and Yucel 2011). The oxidation stability studies were carried out by Bouaid et al., (2009) and the result proved that mustard oil satisfies the oxidative stability when compared to other vegetable oils. Vicente et al., (2005) optimized the method for extraction of mustard oil for biodiesel production.

2.4 Value added products of selected biodiesel plants

2.4.1 Organic manure

Modernization and industrial revolution has destroyed the healthy relationship between the mankind and nature. Day to day the agricultural scenario is changing fast and the task of keeping pace with the population growth is strenuous and challenging. The agriculture should not only be sustainable, but economically and ecologically viable too. Organic manure is a pertinent solution for sustaining the crop productivity and conserves
natural resources thereby fulfills the crop management without degrading the original base. Organic farming is an ecologically balanced holistic approach towards farming. Organic agriculture is defined worldwide as farming without the addition of artificial chemicals.

The Food and Agricultural Organization (FAO) and the World Health Organization (WHO) describe organic agriculture as a holistic production management system which promotes and enhances agro ecosystem including biodiversity, biological cycles and soil biological activity. Also organic farming maintains the ecological balance (Paull, 2007). According to the International Federation of Organic Agricultural Movement (IFOAM) Organic farming is an agricultural system that promotes environmentally, socially and economically sound production of food, fiber and timber. In this system, soil fertility is seen as a key to successful production with natural production of plants, animals and the landscape (Dushyent, 2007). In 1970’s, global movements concerned with pollution and the environment increased their focus on organic farming. In 1972, IFOAM popularized the information on the principles and practices of organic agriculture of all schools, across national and linguistic boundaries. In 1980’s, around the world, various farming and consumer groups began seriously pressurizing for government regulation of organic production. This led to legislation and certification standards being enacted through the 1990’s and to date. Since early 1990s, the retail market for organic farming in developed economies has been growing by about 20% annually due to increasing consumer demand.

In India, ancient culture is a mirror image of a continually functioning civilization. Agriculture has been a way of life rather than a mere economic activity in India. Millions of Indian farmers and adhivasis spread across this vast nation have continued to grow their nutritionally rich and technologically safe crops through organic cultivation. In India, the importance of organic manures in the crop production was well appreciated since the era of early civilization as documented in RIG Veda and elaborately described in Arthashastra, Brihastsamita and Agnipuranam regarding use of animal excreta, bones, fishes, crop residues and other by product of agriculture like oil cakes, slaughter house waste, poultry manure etc. These play an important role in maintaining physico-chemical and biological properties of soil. Atharva Veda indicated the importance of green manure which was practiced before 1000 B.C. Kautilya’s Arthashastra recorded the use of manure such as oil cakes and excreta of animals (Purohit, 2007).

To achieve sustainability in agriculture, there has been a resurgence of interest in several alternative production technologies, out of which organic farming is considered as a vital one. Continuous use of chemical fertilizer and pesticides in agriculture is
contaminating food and feeds and causes health hazards to human and livestock. The health hazard associated with heavy metals entering the food chain through fertilizer is seeking attention. The deficiency of micronutrients is becoming a yield limiting factor in the soils. Organic farming produces healthy crops by way of maintaining the quality of the soil and surrounding environment (Dhakar, 2007; Shaktawat, 2007). Fertilizers are added to the soil to supply one or more elements required for plant growth and productiveness. Organic fertilizers include properly managed farmyard manure, compost and green manure.

Vermicompost is a nutrient-rich, natural fertilizer and soil conditioner. The process of producing vermicompost is called vermicomposting. The act of collecting and utilizing organic wastes and converting them into manure was known to the Indian, Japanese and Chinese from very ancient times (Swami, 2007). India produces organic wastes which include municipal solid wastes, poultry manure and kitchen wastes. India with very large land area has adequate sunlight and water with huge quantities of biomass (Rawat, 2007). Currently the most popular and widely employed technique for solid wastes disposal relies on vermicomposting of organic waste. This versatile technique yields organic fertilizers recovers energy rich resources makes safe disposal of organic wastes and solves the spreading problem of environmental pollution (Adarsh Pal Vig and Arvinder kaur, 2007). Vermicompost is a source of soil carbon and humus and activates soil micro-organisms involved in transformation of nutrients. It also improves soil structure, aeration and water holding capacity. It provides balanced nutrition to crops, better quality products and provides resistance to plants against plant pathogens and insects thereby reducing the requirements of agrochemicals. It reduces the pollution of soil, water and food products by recycling of farm waste. Vermicompost is rich in nitrogen, phosphorous and potassium and forms a good source of nutrients such as zinc, copper, calcium, magnesium, sulphur and cobalt (Acharya, 2007).

Non-edible oil such as Castor cake, Karanja cake, Neem cakes are used as organic nitrogenous fertilizers due to their richness of N P K content. Some of these oil cakes are found to increase the nitrogen uptake of the plant since they retard the nitrification of the soil. They also protect the plants from soil nematodes, insects, and parasites and can provide great resistance against diseases. The seedcake of biodiesel plants finds a potential application in croplands and other types of energy production. Usually the oilcakes such as neem, cottonseed, castor, sesame, mustard, coconut, linseed, soyabean are used as concentrated organic manures for the cultivation of crops because of their valuable N, P, K
contents. Oilcakes of mustard, castor, linseed, mahua were reported to be useful manures (Shenoi, 2003).

2.4.2 Biopesticides

The organic farming concerns two major aspects of alternate agriculture. One is the substitution of organic manures and vermicompost instead of fertilizers and other one is the biological pesticide to replace chemical pesticide. Biological control of pest is of prime importance to organic farming for maintaining ecological balance. Natural pesticides such as neem and other plant extracts are the best ways to combat pests without the use of toxic chemicals (Chakraborty, 1998). Oil cake is a solid residue obtained from a variety of oily seeds. The residue was usually extracted by pressing of seeds. India is one of the world’s leading oilseeds producers and the annual growth in oil cake production is projected to average 2.3% annually (Ramachandran et al., 2007). The other possible uses for seedcake are as charcoal, animal feed and utility in bioproceses for the production of industrial bio-products, enzymes, antibiotics, biopesticides and vitamins (Ramachandran et al., 2007).

A number of antimicrobial by-products such as organic acids, hydrogen sulfide, phenols, tannins and nitrogenous compounds are released during the decomposition of organic amendments or synthesized from microorganisms involved in such decomposition (Rodriguez-Kabana et al., 1995). The cake left after extraction of oil from neem is excellent organic manure with insecticidal properties to control soil insects and nematodes (Antony et al., 2011). The cake from Jatropha has been used as a pesticide in selected field crops (Solsoloy and Solsoloy, 1997; Kumar and Sharma, 2008). Neem cakes contain high amount of organic nutrients and Azadirachtin. They are best used as organic fertilizer and nematicide (Janssens and Pohlan, 2003). Neem has been found to be effective in the management of about 200 insects, pests and nematodes. It is very effective against grasshoppers, leaf hoppers, plant hoppers, aphids, jassids, and moth caterpillars (Venkatesan et al., 1987; Nilima Prabhaker et al., 1999; Srinivasrao and Rajendran 2002; Lingappa et al., 2002; Varghese, 2003). Neem cakes reduce the rate of nitrification to increase the nitrogen availability to plants and reduce the possibility of pollution of ground water and aquatic environments.

The high azadirachtin content protects crops against parasite nematodes (Vanderlinden, 2003; Purohit, 2006). Derivatives of neem oil and cake are sources of environmentally safe agro-chemicals for the control of pests (Shenoi, 2003). Khan and Saxena (1997) reported improvement in tomato plant growth with reduced nematode growth in neem cake amended soil. Similar study using some nematicide such as aldicarb,
carbofuran along with oilcakes such as linseed, mustard and neem controlled nematodes (Shukla and Haseeb, 1996). Use of oilcake offers good alternative biopesticide as value added products during the production of biofuel (Ramachandran et al., 2007). Vidyarthi et al., (2002) have reported the use of cotton based biopesticides in the management of pests. Anis et al., (2010) evaluated the effect of mustard and cottonseed oil cakes for the control of charcoal rot of sunflower and observed a pragmatic decrease in the colonization of *M. phaseolina* while using cotton cake.

### 2.4.3 Animal feed

Oil cakes are of two types, edible and non-edible. Edible oil cakes are characterized by increased nutritional value especially in the form of protein ranging from 15% to 50%. Their composition varies depending on their variety, growing condition and extraction methods. Due to their rich protein and mineral content, edible oil cakes are used as animal feed, especially for ruminants and fish. Seedcakes have different ratios of proteins, lipids, and carbohydrates, producing varying types of products for use as animal feed. Non-edible oil cakes are characterized by the presence of toxic substances making them unfit for use as animal feed (Ramachandran et al., 2007). Because of the high gossypol content, a maximum inclusion rate of 30% cotton seed oilcake in fish feeds are recommended (Pouomogne, 2007).

Homemade feeds from oilseed cake category include soybean, groundnut, linseed, neem, castor, mustard, sesame and sunflower. They are extensively used in cattle and poultry feeds. Other cakes such as cottonseed cake are used as a main ingredient of the feeds (Uppal et al., 2004). Chuadhary and Jat (2008) studied the effect of different dosage of feeding of cottonseed cake and evaluated the milk yield and reproductive performance of surti buffaloes. The results showed that higher dosage of cottonseed in the diet substantially improved the milk yield and post partum reproductive performance of buffaloes. Shinde and Sankhyan (2008) evaluated the mineral contents of cottonseed cake and developed the strategies for improving the method of feed practices of cattle.

There are several alternative ways to utilize the oil cake such as cattle feed, feedstock for biogas plant, feed for vermiculture, biomanure, biofertilizer and biocides. The use of oil cake as biofertilizer especially in cultivation of vegetable crops gained importance due to organic food over non-organic ones. The oil cake is proven to be used as a good fertilizer besides improving the soil fertility. As many of the oil cakes are reported to be water soluble, they can be a suitable organic pesticide for control of pests associated with many vegetable crops. Neem seedcake along with soybean meal had significantly improved
the growth of Broiler chickens (Ahmed et al., 2014). Garg et al., (2008) reported that mustard oilcake is rich in calcium content to be used as a supplementary feed for milch animals. Tyagi et al., (2008) observed that mustard oil cake is rich in glucosinolates and can be used as a protein rich dietary supplement to increase the growth performance and digestibility of crossbred calves.

In Myanmar, sesame meal is one of the common feed supplements for the draft cattle (Gebremariam, 2009). Sesame Cake contains 40–50% protein when processed in a screw press and 56–60% protein after solvent extraction. Sesame products have a pleasant flavor and contain high levels of methionine and cysteine. The flour produced from sesame meal has a high nutritive value compared to other oilseed flours (Salunkhe and Desai, 1986). The protein content, acceptability, and enzymatic digestibility of the meal is also high compared to soybean meal (Johnson et al., 1979). Despite the presence of gossypol, cottonseed cake has gained more importance primarily due to its high content of protein and several other valuable components in cottonseed byproducts (Redhead, 1989). A number of commercial products from defatted cottonseed have been extensively used. Flour produced from cotton seed contained 55–60% protein and 4.5% fat (Lusas and Jividen, 1987). This product was a non-allergenic dietary protein source contributing functionalities such as emulsification, antioxidation and water absorption to bakery based products.

Cottonseed meal is second to soybean meal with respect to the quantity produced worldwide. Cottonseed meal is used for cattle, sheep, goats, horses, and mules (Bangani et al., 2000; Pickard, 2005). Neither glandless nor normal cottonseed meal is palatable to young pigs (Bell, 1989). Broiler poultry feeds often contain cottonseed meal with the potential to improve weight gain and feeding efficiency. Cottonseed is increasingly being used as protein sources for humans, as well as pets and livestock. Kittens grew at an acceptable rate when glandless cotton seedcake provided approximately one-third of the dietary protein. Kittens preferred the cottonseed diet over a soy diet. Regular cotton seedcake can also be used as a protein supplement for nursing calves. Nursing calves whose diet is supplemented with regular cottonseedcake had a higher daily weight gain than animals fed with normal diet (Alford et al., 1996). Anil kumar et al., (2002) have reported mustard oilcake as a source of dietary protein for growing lambs. Cotton and mustard oilcake enhanced the protein content of bovine milk (Ullah et al., 2011).
2.5 Potential and feasibility of biofuel production from selected medicinal plants

Radha and Manikandan (2011) optimized the protocol for production of biodiesel from neem oil. They demonstrated that biodiesel produced from neem oil could reduce smoke, carbon monoxide emissions significantly. Zaku et al., (2012) compared the functional properties of neem, *Jatropha*, castor and moringa seeds oil as potential feedstocks for biodiesel production in Nigeria. They recommended that all the oils have good physiochemical properties and served as promising precursors for biodiesel production. Muthu et al., (2010) improved the methods for synthesis of biodiesel from neem oil through transesterification using sulfated zirconia as a catalyst. Tyagi and Sharma (2012) investigated the performance and emission characteristics of neem oil blends and reported B20 blend results in better performance and lower emissions. Yadav and Shrivastava (2012) refined their experiments to analyze the performance of different blends (B20, B50 and B100) of neem oil biodiesel and showed B20 with a close performance to plain diesel.

Atabani et al., (2012) reported cottonseed oil as a potential source for biodiesel production in Greece. Neha et al., (2013) have optimized the production of biodiesel from cottonseed oil using sodium hydroxide as a catalyst. Leiras et al., (2008) analysed the economic feasibility of biodiesel in a complete supply chain and developed an economic evaluation model. Ashraful et al., (2014) refined the production of biodiesel from cottonseed oil along with nine other non-edible oils and demonstrated the performance of blends equivalent to those of commercial fuel. Joshi et al., (2008) improved the biodiesel properties of cottonseed oil and its blends and their ranges lie within the ASTM values. Jo-Han et al., (2010) optimized the biodiesel for application in CI engines. Rizwanulfattah et al., (2013) reviewed the facts and prospects of cottonseed oil to reduce engine exhaust gas, noise emission and petro dependency and this attempt was successful. Gnanaprakasam et al., (2013) reported that maximum enzymatic conversion to biofuel of cottonseed oil was obtained at 50°C.

Due to high lubricity, biodiesel derived from castor oil could achieve the required biodiesel standards at much lower concentrations (Helse, 2014). Thananchayan et al., (2013) fine-tuned the kinetics of the transesterification reaction to produce biodiesel from castor oil. Islam et al., (2014) investigated the diesel engine performance and reported that the specific fuel consumption of biodiesel blend was increased sufficiently when the blending ratio was optimized. Silva et al., (2013) characterized the blend properties of castor biodiesel and bioethanol and declared that the decrease in biodiesel viscosity with the addition of bioethanol enhanced the ideal properties of biodiesel. O'Donnell et al., (2013) reviewed the spectroscopic analysis of castor oil for optimal biodiesel production.
Betiku and Adepoju (2013) employed response surface methodology to optimize the biodiesel production from sesame oil and reported that fuel properties of biodiesel produced were found within the range of ASTM and EN specifications. Ahmad et al., (2011) refined the qualitative and quantitative analysis of sesame oil biodiesel and concluded that sesame oil biodiesel can be used as an environment-friendly renewable fuel. They also added that sesame is one of the potential, low priced biodiesel sources. Al Mamun et al., (2013) extracted biodiesel from sesamum and optimized the efficiency of production rate based on its fuel properties. They demonstrated that fuel properties of biodiesel produced by sodium hydroxide as a catalyst were better than those produced by sodium methoxide as a catalyst. Bari et al., (2012) fine-tuned the production of biodiesel from sesame and soybean as an alternative renewable fuel for diesel engines.

Sanjid et al., (2013) reviewed the impact of mustard oil biofuels along with palm, waste cooking oil and calophyllum biofuels for sustainability of feedstock and compared the performance and emission of these biofuels. They reported that mustard oil is a new promising source of biofuel especially for NO$_x$ reduction. Tulip and Radha (2013) investigated on the potential use of mustard oil as feedstock for the production of biodiesel. They found that when a blend of B20, B40 and B60 were used, NO$_x$ emission was reduced significantly and B20 serves to be better than other blends with regard to exhaust temperature, brake specific fuel consumption. In a similar way, Sarala et al., (2012) refined the emission characteristics of mustard oil methyl ester diesel fuel blends on a CI engine. Sharma et al., (2013) investigated the performance of single cylinder CI engine using mustard oil biodiesel and proved the potentiality of mustard biodiesel. Hongcong (2013) reported mustard oil biodiesel as a promising alternate fuel for CI engines.

2.6 Importance of the present study

In India, the main source of energy is obtained from fossil fuels and the demand for energy keeps on increasing. The energy crisis arises as a result of population growth and increasing consumption of energy in both developed countries on pace with emerging economies. The greater demand for petroleum products as a result of an enormous increase in the number of automobiles lead to the growing problem in India. With crude oil reserves estimated to be last within few decades, efforts are on way to find out new alternatives to diesel. The depleting petroleum fuel resources, price hike, non-renewable nature and the emission of pollutant urges the need for the development of an alternative source of eco-friendly fuel. Depletion of crude oil would cause a major impact on the transportation sector in the future.
Of the various alternate fuels under consideration, biodiesel derived from vegetable oils, appears to be the most promising alternative fuel to diesel. Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. More than 95% of the world’s biodiesel is produced from edible vegetable oils, thereby increasing demand throughout the world for vegetable oil production and thus competes with demands in food sector. In the past few decades, the most commonly used oils for the production of biodiesel is soybean, sunflower, palm, rapeseed, and canola. Since the prices of edible vegetable oils are higher than that of diesel fuel, waste vegetable oils and non-edible crude vegetable oils are preferred as potential, low priced biodiesel sources. The biodiesel from vegetable oils increases the cost of food around the world and forests are being cleared to grow the biodiesel crops which compete with the agriculture for land and water. The non-edible oils obtained from the crops grown in non-agricultural and non-forest lands offer a worthy solution to these issues. The contributions of non-edible plant oils as a new source for biodiesel production have the advantage of not competing with edible oils produced from crop plants.

Considerable amount of research has already been carried out to use vegetable oil both in its pure form and also in modified form. In recent years, the use of biodiesel as alternative source of fuel has been extensively investigated with the objective of ensuring energy security and reducing the environmental impacts of fossil fuel emissions. Studies have shown that the usage of edible/non-edible oils in pure form is possible but not preferable. Biodiesel can be used in neat (100%) or blended with the conventional diesel fuel up to 20% to create a biodiesel blended fuel for its use in the CI engines. It can be used as a standalone fuel or blended with petroleum diesel in diesel engines without any engine modifications.

Considering the growing need of biodiesel, the present study was undertaken with the following objectives. The primary objective of this study is to analyze the physico chemical properties of the oils from Neem (Azadirachta indica), Cotton (Gossypium hirsutum), Castor (Ricinus communis), Gingelly (Sesamum indicum), and Mustard (Brassica juncea) for biodiesel production with novel ultrasonic studies. The second objective includes the evaluation of micro and macronutrient status of oilcakes for possible utilization as biomanure for commonly cultivated short term crops such as paddy, onion and chilly.