Chapter:1

INTRODUCTION

1.1 Worldwide status quo of fossil fuels

For more than two centuries till date, the world's energy supply has relied heavily on non-renewable crude oil derived (fossil) liquid fuels. This fossil fuels consists of oil, natural gas and coal, of which 90% is estimated to be consumed for energy generation and transportation. Since the oil crisis in 1973, the global oil price has increased dramatically from USD 2.8 per barrel in 1973 to USD 93.0 per barrel in 2011; (http://www.oil-price.net/). However this has not reduced the worldwide demand for oil. Likewise, this is similar for consumption of coal and natural gas as well (Figure 1.1). The trend of this increasing demand for fossil fuels will remain and it is predicted that by 2030, the energy consumption from fossil fuels will grow by approximately 30% (British Petroleum, 2011). As demand for fossil fuels is increasing particularly in developing countries such as China and India, it is likely that these crude oil reserves could be depleted in less than 50 years at the present rate of consumption (Devensan *et. al.*, 2007).

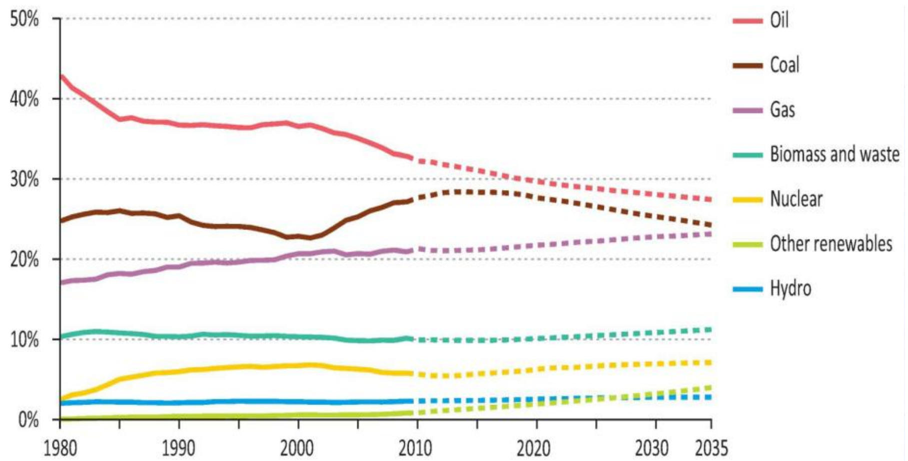

Fig.1.1: Shares of energy sources in world primary energy demand

(*Source:* World energy outlook, 2011)

1.2 Oil Energy Scenario of India:

From the very beginning, India's energy scenario has been a mixed characterization of commercial and non-commercial sources of energy, which are namely cow dung, agricultural wastes, coal, hydro, oil, gas and presently nuclear energy. The steady rise in energy consumption over the past decade has been accompanied with changes in the relative share of different fuels. About 31% of India's primary energy needs are met from bio-energy produced on a non-commercial basis from agricultural and forest waste, wood chips, animal waste and bio-fuels (Gokhale: 2006). The country currently ranks as the world's seventh largest energy producer, accounting for ~2.49% of the world's total annual energy production. It also the world's fifth largest energy consumer, accounting for ~3.45% of the world's total annual energy consumption in 2004 (http://planningcommission.gov.in/). India imported 13.4% of its coal requirement, 73.4% of oil and its products and 1.6% of gas requirement. India’s net imports of 131.97 mt in 2006-2007 includes the import of 95.43 million tonnes of crude oil and petroleum products, 44.29 million tonnes of coal and 5.0 million tonnes of LNG.

Indian oil consumption has grown from 60 mtpa in 1991 to over 125 mtpa in 2007. Only in the last few years oil share has grown to 36% of total energy consumption (Mukundan: 2009). Total crude demand has grown by more than 6% annually (Winrock International India: 2008) and petroleum products consumption has grown by 8-9% per annum (Rajvanshi: 2007). Overall demand of crude oil has raised by 5.6% until 2011 (ICRISAT: 2008). Diesel accounted for 60% rise, due to its use in the commercial transport sector and as a fuel for small-scale electricity generation (CGES, 2008). At the same time, the country's annual per capita energy consumption with 480 kg oil equivalent is quite low (Bhattacharya & Joshi: 2003, Singh, *et. al.:* 2006, Kumar, *et. al.:* 2008).

Even though indigenous oil production has increased from 0.45 million tons in 1960-1961 to 34.12 million tonnes in 2007-2008, India's crude oil and natural gas production has stagnated in recent years (Tables 1.1 & 1.2) (Riemer & Von Lonski, 2008). Domestic supply can presently satisfy only 22% of annual crude oil requirement of 111 million tons and, therefore, dependence on crude oil imports to the tune of 18 billion USD/yr (71,784 crores Rs./yr, ~9.1 billion GBP/yr, using exchange rate USD/GBP = 0.503, GBP/INR = 79.23 - April 2008. www.xe.com/ucc/convert.cgi) is increasing. As such, there is a growing demand gap between production and consumption and thus, the result has been a rapid rise in oil imports (Tables 1.3), which increased from 21 million tons in 1990-1991 to 111 million tons in 2006-2007 (Winrock International India: 2008). This account for ~30% of India's total import bill (Mukundan: 2009) and ultimately India's oil import dependency is projected to rise to 91.6% by 2020 (Scaife, *et. al.*,2006); 93% by 2030 (Altenburg, 2009).

Table 1.1: Increasing crude oil demand and supply gap in India (million tons)

	Demand	**Supply**	**Gap**
2001-2002	99.70	32.03	67.67
2002-2003	114.30	33.05	81.25
2005-2006	140.00	33.98	106.02
2011-2012	199.60	33.47	166.13
2024-2025	376.50	61.40	315.10

Source: IBEF (2008).

Table 1.2: Increasing crude oil demand and supply gap in India (million tons)

	Demand	Supply	Gap
2001-2002	151.00	81.40	69.60
2006-2007	231.00	94.84	136.16
2011-2012	313.00	158.05	154.95
2024-2025	391.00	170.00	221.00

Source: IBEF (2008).

Table 1.3: India's import burden of crude

Demand of petroleum products	146 million tons
Production of crude	35 million tons
Import of crude	111 million tons

Source: Winrock International India (2008).

1.3 Development of alternative fuel sources

It is well known that emissions from the combustion of these fossil fuels such as CO_2, CO, NO_X and sulphur containing residues are the principal causes of global warming. On the other hand, known crude oil reservoirs could be depleted in less than 50 years at the present rate of consumption (Devansen *et al.*, 2007).Therefore in recent years increased environmental concerns, tougher clean air act standards necessitates the researchers to explore plant-base fuels, because it is renewable, non-toxic, biodegradable and environment friendly. This biodiesel can be made by the transesterification of triacylglycerides obtained from vegetable oils or animal fats with short-chain alcohols.

This transesterification can either be achieved chemically or enzymatically using lipases. This process considerably reduces the viscosity of the oil to a level similar to that of petrodiesel (Srivastava and Prasad, 2000). One hundred years ago, Rudolf Diesel tested vegetable oil as fuel for his engine. With the advent of cheap petroleum, appropriate crude oil fractions were refined to serve as diesel fuels and diesel engines evolved together (Ma *et al*., 1999). Compared to petroleum diesel in diesel engines, biodiesel greatly decreases the emission of CO, sulphur, hydrocarbons, particle matter and smoke during the combustion process. Furthermore, burning biodiesel has no net addition to atmospheric CO_2 levels, because it is made from agriculture materials produced via photosynthesis carbon fixation (Shu *et al.,* 2003). Thus the attractive features of bio-diesel fuel are: (i) it is plant–derived, not petroleum–derived and as such its combustion does not increase current net atmospheric levels of CO_2 & CO (greenhouse gases); (ii) it can be domestically produced, offering the possibility of reducing petroleum imports; (iii) it is biodegradable; (iv) relative to conventional diesel fuel, its combustion products have reduced levels of particulates, carbon monoxide, sulphur oxides, hydrocarbons, soot, and under some conditions, nitrogen oxides (Antolin & Tinaut, 2002). Vegetable oils can be used in diesel engines as they have a high octane number and calorific value very close to diesel (Devansen *et al*., 2007).

In recent years, increased global industrialization and increased demand for livestock products for meeting human food demands have greatly increased the pressure on agricultural land and the environment (Steinfeld *et al*., 2006 & Rosegrant *et al*., 2001). On a global scale, the area of degraded land is much larger than the 1.4 billion ha. under agricultural use and increases by approximately 10 million ha. every year. Assuming that an average grain yield on that land of 2.5 t only per hectare could be achieved, these 25 million tons of grain would be sufficient to feed an additional 100 million people (Costanza *et al.* 1997). Therefore, it is important to prevent the degradation of fertile land and to reclaim already lost cropland. Also the higher need for proteins in the livestock sector has accentuated the search for new protein sources that do not conflict with human food security interests. In the current situation, non-edible oil seeds are the potential and preferred choice for protein and other nutrients for livestock, provided these could be made free of toxic and anti-nutritional factors.

In most developed countries, biodiesel is produced from soybean, rapeseed, sunflower, groundnut, sesame, palm oil which are essentially edible oils and thus face high demand and more expensive than diesel fuel. In this case non-edible oil sources such as *Jatropha curcas*, *Pongamia pinnata* would be potential biodiesel source for most of the developing countries (Karmee & Chadha, 2005; Meher *et al.*, 2006; Tiwari *et al.*, 2007, Naik *et al.*, 2008 and Berchmans & Hirata, 2008). Rao *et al.* (2008) stated that because of the wide adaptability to grow under various agroclimatic conditions, for example, adverse soil conditions, drought areas, marginal lands, arid as well as higher rainfall conditions, and land with thin soil cover, *Jatropha curcas* has advantages over other oilseed plants (e.g., *Pongamia pinnata*, *Simarouba glauca*, *Ricinus communis*, *Azadirachta indica*). Most importantly, jatropha seed oil has gained tremendous interest as a feedstock for biodiesel industries**.**

1.4 *Jatropha curcas* L. and its potential as a feedstock for biodiesel production

1.4.1 Botanical description of *Jatropha curcas*

Jatropha curcas Linn. known as physic nut or purging nut is a plant belonging to tribe Joannesieae in the family Euphorbiaceae (Sirisombon *et al.*, 2007 and Kumar & Sharma, 2008) and is a small deciduous tree (up to 5 m) which originates from Mexico and Central America, although nowadays its growing pantropic (Heller, 1996 and Ratree, 2004). The name "*Jatropha*" is derived from the Greek 'iatros' (doctor) and ‘trophe’ (food). There are two genotypes of *Jatropha curcas*, a toxic and a non-toxic one. The later genotype is found only in Mexico. *Jatropha* is a diploid species with 2n = 22 chromosomes. It is a succulent plant that sheds its leaves during the winter season (Kumar & Sharma, 2008). It is, therefore, best adapted to arid and semi-arid conditions. It grows on well-drained soils with good aeration and is well adapted to marginal soils with low nutrient content (Sirisombon *et al*., 2007; Kumar & Sharma, 2008 & Heller, 1996). Jatropha appears well adapted to conditions of low to very low soil fertility, and mineral deficiency symptoms are rarely observed. The plant must has an enormous capacity to absorb and utilise nutrients under low fertility conditions as it grows well even on the poorest, mostly P-deficient and acid soils such as those found on the Cape Verde Islands (Makkar & Becke, 2009). Its drought tolerance and adaptation capacity to long, severely dry seasons are well developed and have been reported to grow even where there is no rain for 2–3 years (Münch & Kiefer, 1989). On the other hand, *Jatropha* appears to tolerate humid conditions equally well, showing good growth with high rainfall. *Jatropha* is therefore highly adaptable to varying precipitation conditions. However, heavy rains at the time of flowering could lead to the complete loss of flowers and also *Jatropha* does not tolerate instantaneous flooding. It has been found that the temperature range of 25^0–35^oC is optimum for *J. curcas* growth, but in some regions like the tropics it may be found at higher altitudes with the risk of light frost. On the other hand, Jatropha can tolerate elevated temperature to far above 40^oC (Makkar & Becke, 2009 and Kinawy, 2010).

The plant bears simple leaves, orbicular-ovate, angular or somewhat 3-5 lobed, 10-15 cm long, acuminate and base cordate with long petioles (Ross, 2003). Ciliate glands usually represent the stipules. The venation is palmate. The leaves are green to pale green broad and glabrous. Phyllotaxy is spiral. Flowers unisexual, monoeceious, greenish yellow in terminal long, peduncled paniculate, cymes. The central flowers in the cyme or in its forks usually female. Calyx as in male, corolla scarcely exceeding the calyx lobes united, villous inside, carpets connate into a 3-celled ovary, styles 3 connate at base, stigma bifid, ovules solitary in each cell. The flowers are greenish or greenish-white, 6-8 mm in diameter. Pollinations by insect. After pollination fruit developed is usually a three chambered and schizocarpic capsule splitting into three one-seeded cocci. The exocarp remains fleshy until the seeds mature (Heller, 1996). Each inflorescence yields a bunch of ovoid fruits. Each fruit bears three to four seeds. The seeds are albuminous, tesla crustaceous. It is a diploid species with 2n = 22 chromosomes. Seeds resemble castor in seed shape, ovoid oblong and black in colour. The seeds become mature when the capsule changes from green to yellow and then to blackish, after two months of fruit setting. The seeds are blackish. The nut is a violent purgative.

Despite the several merits, *Jatropha* could not be domesticated yet as a potential oil crop and it is still considered as a semi-wild plant (Achten *et al.,* 2010). Large scale plantations may give it a semi wild status, which will determine its domestication prospects in due course of time depending on its benefit: cost ratio. It grows well on degraded soils of low fertility. In fact, this assumption is based on the premise that such soils have low potential for economically viable agriculture and their use for the cultivation of jatropha would not be in conflict with food production. Since arable land cannot be diverted for jatropha cultivation, its prospects on poor, marginal, degraded, derelict, denuded, desolated and abandoned lands are being looked for biofuel production (Misra & Murthy, 2011).

Reliable scientific data on jatropha genetic diversity, agronomy, physiology and economic benefit are currently increasing in the scope to breeding new line and to optimize the production in a wide range of agro-ecological conditions. Although various approaches using RFLP, AFLP, SCAR and ISSR markers have been carried out to assess genetic diversity and origin of *J. curcas* accession, no conclusive explanation has been inferred (Basha & Sujatha, 2007; Sudheer *et al.*, 2008 & 2010 and Ranade *et al*., 2008). Studies on *Jatropha* collected in Northeast India (Assam and Meghalaya) revealed genetic diversity at intra-population level but moderate diversity at inter-population level (Kumar *et al*., 2011 & 2013). Recent attempt to assess the effects of different agronomic treatments (spacing, pruning, irrigation and fertilization) on growth and seed yield of *Jatropha* at seven locations of India including the Northeast was carried out with a contribution in *Jatropha* agro-technology standardization in different climate area and non-arable Indian lands (Singh *et al*., 2013). Furthermore, economic benefits of *Jatropha* plantation in Northeast was also estimated as economically viable but development of new varieties and field and post-harvest management operation are required to make *Jatropha* plantation more attractive (Goswami *et al.,* 2011).

1.5 Objectives of this study:

From several years the CSIR-North East Institute of Science and Technology (CSIR-NEIST) was involved in research project on growth performance in the Northeast of *Jatropha curcas* accession collected around India resulting in a first screen of satisfactory performance of some accessions in the conditions of Jorhat on the basis of morphology, growth and yield (Saikia *et al*., 2009). The present study was undertaken to increase the knowledge and compare the agronomy and physiology of plants as well the biochemical oil characteristics of 24 jatropha accessions collected from various localities of North-East India in the light to contribute for future selection of ideotypes with low undesirable free fatty acids content and potential valorization of secondary oil products (PEs, tocopherols) to enhancing economic viability and sustainability of the jatropha oil-based biodiesel chain.

Thus the main objectives of this study are as follows:

- **a)** Collection of *Jatropha curcas* L. accessions from different localities of North-East India and establishing them at CSIR-NEIST experimental field.
- **b)** Study of growth, morphological, physiological and flowering parameters to find out the source variations among the accessions.
- **c)** To determine the magnitude of variation in total seed yields and oil content for each and every accessions.
- **d)** Biochemical analysis of crude seed oil (*i.e.* quantification of Free fatty acids, tocopherol % and phorbolesters).
- **e)** Analysis of variations in genetic compositions of all the 24 accessions by different molecular techniques.