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REVIEW ARTICLE **OPEN ACCESS**

Plants with Biodiesel Potential in India: A Review

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ABSTRACT
India's energy demand which comprise of coal, natural gas and oil has been increasing in a rapid pace in recent times due to growth of economy as well as rapid industrialisation. India being the fourth largest consumer of crude oil in the world has to depend on other countries to meet the energy demand. With the sharp rise in oil prices till present times has severely affected the economy of the country. Moreover till date, the entire oil industry in India is dependent on fossil fuels whose reserves are decreasing throughout the world and also non-renewable, non-biodegradable causing lots of environmental pollution. Biodiesel is one such alternative which has already become an integral part in countries like USA, Europe, China and Brazil. This paper reviews the potential biodiesel plants prevalent in India like sunflower, castor bean, soyabean, sesame, linseed and cotton which must be taken into consideration for a healthy and secure future in terms of energy.
Keywords: Biodiesel, plants, renewable, energy, environmental friendly.

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INTRODUCTION

India being one of the fastest growing economy in the present world requires energy in adequate amount. This energy requirement is entirely dependent on fossil fuels from the past few decades and may continue to do so for the next few coming decades too. But this fossil fuel reserves are very limited and are decreasing in the entire world. In addition to this they are non- renewable, non-biodegradable and therefore polluting the environment. Moreover the increase in oil prices from recent past till present has affected her economy to a much wider extent. This emphasizes the need to think of alternative resources which are renewable, biodegradable and environmental friendly. Biodiesel is one such alternative.

The country of India is bestowed with abundant energy resources in the form of energy crops which are indigenous as well as renewable and from which biodiesel could be extracted.

Biodiesel is biodegradable, non- toxic and can be recycled because of high flash point, high cetane number and lowest clouding point [1,2]. Biodiesel reduces engine emissions of hydrocarbons and carbon-monoxide while the engine performance is quite analogous to the conventional diesel fuel [3].Biodiesel or biofuel are liquefied fuels obtained from biological sources having much lower CO_2 or greenhouse gas emissions when compared with conventional fossil fuels [4-7].

In India, biodiesel could be produced from oil producing crops such as sunflower, castor bean, soyabean, sesame, linseed and cotton. But the biofuel industry in India is still at its infancy since raw materials for it originate from the agricultural sector and thus farmers require incentives to grow such crops without compensating their food security.

The National policy on biofuels in India includes 20% blending of biofuel both for biodiesel and bioethanol by 2017 with the ministry of Agriculture's role for promoting research and development for production of biofuel feedstock crops along with the Ministry of Science and Technology supporting biotechnological research in biofuel crops [8]. The principle objective of this policy in India is to reduce the country's dependency on the imported crude oil to meet the energy demand by enhancing its productivity indigenously. Moreover, rapid change in climate through emissions of greenhouse gases led to promotion of biofuels in India which is both environmentally sustainable development and creates new opportunities for employment [9].

Cultivation of crops is dependent on various factors such as sunlight, water, rainfall, soil and nutrients. Many oil producing crops can be cultivated in India for biodiesel production and can also be

commercialised if cultivated on large scale based on the high potential value demonstrated by researchers. Some of the plants are discussed below-

Sunflower

Sunflower (*Helianthus annuus* L.) belonging to the family compositae is a herbaceous annual plant with short duration of maturity. It is one of the important oilseed crops of the world. Sunflower seeds contains 48-53% edible oil, rich in linoleic acid (64%) which helps in preventing cholesterol deposition in the heart and thus is good for patients with heart ailments. It is thus the best edible vegetable oil [10]. Beside this, seed also contains hull (21-27%), protein (14-19%), soluble sugar (7-9%), crude fibre (16-27%) and ash (2-3%) [11]. Every part of sunflower crop is very useful and has been used for variety of purposes such as the dried petals and pollens are used for preparation of face paints while hulls and petals are used in dye preparation. The crop is also used for medicinal purposes such as sunstroke treatment, wart removal to snake bite treatment [12].Besides the seeds being used for oil extraction for human consumption, it can also be used for biodiesel production [13].

Sunflower grows best on high water holding capacity soils with neutral pH (6.5-7.5) and can adapt to wide range of soil conditions. It is also tolerant to low temperatures (8°C) [14,15] and draught and can grow in semi-arid regions of the world without irrigation[16,17].

In India, sunflower is grown throughout the year but its cultivation is mainly confined in the spring season in the north- west region of the country (Punjab, Haryana and western Uttar Pradesh). In North India, it is sown during kharif and spring/ zaid season. Higher yields are obtained during early summer; June to mid July because of low biotic stress and favourable soil moisture condition. Sowing time should be adjusted so as to avoid heavy rains during flowering periods. For rabi season, the suitable sowing time is mid- September and mid-October and for summer/ spring it is January to first week of February [18].

The major sunflower growing areas in India are Karnataka(leading in production), Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa, Bihar and Gujarat. Intercropping system can be done for sunflower with crops such as groundnut, castor, soyabean, blackgram, pigeonpea and finger millet which can be considered as a very advantageous part for this and so must be encouraged for cultivation on a large scale for purpose of biodiesel production. In India sunflower as an oil- seed crop was introduced in 1969 when only 0.1 million hectares were under this cultivation while it has increased to 1.63 million hectares in 2002-2003 [19]. Oilseed production has increased from 24.35 million tonnes in 2004-05 to 30.94 million tonnes in 2012- 2013. Presently in 2013- 14, 28.28 million hectares are under oilseed cultivation and it produced 33 million tonnes. To improve the declining oilseed production in future, government of India is implementing the National Mission on Oilseeds and Oil Palm (NMOOP) 2014-2015 and one of the major strategy is promotion of sunflower cultivation in Zaid season and also encourage oilseed cultivation in areas with low wheat productivity, rice fallows & intercropping with cereals and pulses. Moreover expansion of cultivation will be done on waste lands with elite tree borne oilseeds [20].

Sunflower being a photo-insensitive crop can be grown in any season (namely; kharif, rabi and spring) in India. It takes 80-90 days in kharif, 105-130 days in rabi 100-110 days in spring season. It grows best in loamy soils with good drainage & with soil pH of 6.5 to 8.5 [21].

Oil quality from sunflower seeds differs in different climatic condition and agricultural practices [22]. Therefore further research on this is required in India so as to ascertain the best areas and dates of sunflower cultivation to get quality oil and to consider this plant as a biodiesel feedstock.

Sunflower has already become the alternative cash crop for farmers due to perennial threats of flood and draught over traditional paddy cultivation in coastal Bhadrak district in state of Orissa, India. Moreover geographical area support the cultivation [23]. Sunflower grows in relatively less time (90-100 days) when compared to rice (5 months) and wheat (6 months). This indicates a good profit in much little time [24].

Castor bean

Castor bean (*Ricinus communis*) is a draught resistant, non-edible perennial oilseed crop belonging to the family Euphorbiaceae [25, 26]. It is grown in the arid and semi-arid regions of the world and can survive in diverse climatic conditions [27]. The seeds of castor contain 46-60% oil rich in ricinoleic acid. Besides being used as paints, coatings and as lubricants in industries and in the internal combustion engine of aeroplanes, it is also used in manufacturing candles, soaps and cosmetics [28-30]. Castor oil is best for biodiesel production as it is soluble in alcohol unlike other vegetable oils and can be transformed into fuel without heat and other energy requirement [31].Thus cost for biodiesel production is low compared to other vegetable oils [32]. Castor biodiesel has viscosity almost similar to that of diesel. Moreover fuel properties such as density, flash point and calorific value compare well with the relevant quality standards [33]. India is the world's largest producer of castor and contribute around 85% of world's total production. Gujrat, Rajasthan and Andhra Pradesh are the main castor producing states of India [34].

Castor is a kharif crop and grows best under hot and humid conditions and thus cultivated in tropical countries of the world. In India, the sowing time is July or August and harvested around December or January. It has growing period of 4-5 months and can grow in rotation with crops like green gram, groundnut, joware,bajra, cowpea [35]. Inspite India being major producer and exporter of castor oil in the world, it still buy its formulated products and its derivatives at a cost much higher than that of oil [36]. Indian castor seeds has oil content of 48% and 42% can be extracted. Remaining residual oil cake can be used as organic manure [37].
India having the ideal climate for castor production should take the advantage to produce biodiesel as alternative to diesel fuel and also for energy security of our country where diesel consumption is several times higher than petrol consumption.

Soyabean

Soyabean (*Glycine max*) also known as golden bean or miracle crop is an important legume crop of East Asia. It is better known as oilseed crop rather than a pulse due to its use as vegetable oil and biodiesel production [38]. Soyabean are highly proteinecious containing all essential amino acids required for human body [39]. Soyabeans are processed for oil and protein for human consumption. Some products from soyabean include soy milk, soy flour, soy protein, tofu etc. Besides using soyabean oil in cooking purposes, some packed foods such as tuna, sardines etc also contain soyabean oil. Some of the industrial application of soyabean include candles, soyink, soycrayon, lubricants, soy based foams in coolers and refrigerators [40]. Research study has proved that soyabean crop has the potential to produce biodiesel [41]. Soyabean contain 18% oil and 45% protein. It is a kharif crop grown in tropical, sub- tropical and temperate climates [42]. The optimum temperature for the crop is 20-35°C with annual rainfall of 950 mm [43]. The major soyabean producing countries of the world are United States, Brazil and Argentina and they contribute for 80% of the world's supply. India ranks fourth in soyabean production of the world. In India, the state of Maharashtra and Madhya Pradesh leads in soyabean production by contributing 89% of the total production of the country. While remaining 11% are produced by Karnataka, Andhra Pradesh, Rajasthan, Gujarat and Chhattisgarh [44]. The sowing season of soyabean in India is June-July and the harvesting period is September- October [45].
The main goals of biofuels in developing countries such as India is the energy security and use of degraded lands. Soyabean falls under first generation crops for biodiesel production [46]. The method employed for biodiesel production from soyabean is a transesterification reaction of vegetable oils with methanol or ethanol in presence of sodium hydroxide catalyst to yield methyl or ethyl esters (biodiesel) and a byproduct of glycerine [47].
In India, soyabeans are mainly used for soya oil, oil cake and oil meal [48]. India, besides being dependent on the edible products of soyabean crop, efforts should also be taken to produce biodiesel from this miracle crop. This will only help India to go a step forward in the oil production sector and save its country's economy in near future like other advanced countries such as United States, Brazil and Argentina which already has been producing biodiesels in a much successful way from years before.

Sesame

Sesame is an annual oilseed crop of the tropics and the sub-tropics and grows best on moderately fertile, well drained soils with pH of 5.5-8.0. This crop is sensitive to salinity and water- logging but can grow in poor soils and is very draught tolerant [49, 50]. The sesame cultivation is done in countries such as India, China, Burma, Sudan, Thailand, Egypt, Mexico, Bangladesh, Pakistan, Sri Lanka, Indonesia, Saudi Arabia, Turkey and recently it is carried out in semi arid regions as well [51].
Sesame seeds contains oil content (46%-50%), unsaturated fatty acids (83%-90%), proteins (20%) and large amount of lignans such as sesamin, sesamol, tocopherols in addition to minerals and vitamins [52]. Sesame seeds also known to have medicinal properties such as antioxidative, anticarcinogenic, anti-inflammatory and anti-hypertensive and are consumed for such human health benefits [53,54]. Research studies on sesame seeds has proved that its methyl ester has the potential to produce biodiesel much successfully[55,56]. The agro climatic condition of India is well suited for sesame cultivation. India occupies 6th position in sesame production after soyabean, cotton seed, groundnut, sunflower and mustard[57]. Sesame besides being used as edible oil, its oil is also used for manufacturing soaps, cosmetics, perfumes and pharmaceutical products [58]. The fuel properties of sesame biodiesel such as specific gravity, flash point, pour point, kinematic viscosity, cetane number, sulphur content have been found to give equal performance when compared with (mineral) traditional diesel and even at 100% biodiesel there was no obvious change in engine power [59]. In India, sesame is cultivated in all seasons of the year (Kharib (June-July to Sept-Oct), pre-rabi, rabi, summer) due to short duration of the crop cycle [60]. Gujarat leads in sesame production in India followed by West Bengal, Karnataka, Rajasthan, Madhya

Pradesh, Tamil Nadu, Maharashtra, Andhra Pradesh [61].Sesame being an arable crop can be grown without irrigation and can thrive on marginal soils with amended soil nutrition [62]. The top five sesame producers of the world according to rank are China, India, Sudan, Myanmar, Uganda which account for 70% of the world's production. India, China, Mexico are the major exporters of sesame seeds [63].
In a country like India where 79% crude oil is imported to produce petrol, diesel, kerosene and cooking gas due to higher demand the need to think of alternative fuel becomes a must [64]. At present although India ranks 2nd in the sesame production of the world, its seed are only cultivated for human consumption till date. This seeds which have the potential for biodiesel production and can grow in even poor marginal soils, such lands should be kept for the alternative fuel cultivation in near future without affecting the food security of the country.

Linseed

Linseed (*Linum usitatissimum*) also known as flaxseed oil is an important oilseed crop of the world. Canada accounts for 80% of linseed production of the world followed by China, US and India [65]. Linseed is an annual crop grown in temperate and tropical regions of the world and grow up to 60 cm in height. Linseed contains 30-40% oil, stearic acid (5-6%), oleic acid (15-17%), linolenic acid (50-58%), linoleic acid(14-16%) and palmitic acid(4-6%) [66]. Every part of the linseed plant is useful. The oil obtained from linseed is used in the manufacture of varnish, paints, pad-ink, printed-ink, oil cloth, linoleum etc. The oil cake obtained is a good feed for cattles and is also used as organic manure. Fibres obtained from linseeds is used in manufacture of linen while fibres from the stems has good strength and durability. Quality papers can also be made from the linseed obtained short fibres [67]. Linseed oil can be used to produce biodiesel by transesterification process in which higher fatty acids are converted to methyl and ethyl esters using KOH as catalyst and methanol [68]. Several research work has been done worldwide to investigate the potential as biodiesel from linseed oil such as temperature, injection pressure on engine performance and also the effect of its use in diesel engines [69-71].
In one experimental study, linseed biodiesel blend of B20 (i.e, 20% ratio on volume basis) was found to be optimum fuel in terms of better performance and reduced carbon monoxide and hydrocarbon emissions when compared to diesel fuel [72] while in yet another study, it was found that non- edible linseed oil possesses density, flash point, fire point comparable to that of traditional diesel fuel which again indicate it to be a valuable alternative to fossil fuel [73]. In India, linseed cultivation is done because of favourable climatic condition and soil condition. Globally, India is the third largest producer of linseed. The major linseed producing states of the country are Madhya Pradesh(leading state), Uttar Pradesh, Bihar, Rajasthan, Orissa, Karnataka, Chhattisgarh [74]. In India linseed is a rabi crop which is sown during October-November and harvested in February-April. Therefore it is also called as a cool season crop as the seed crop does well in moderate cold (21-26°C) but thrives best under moist cool climate [75]. Linseed can be raised in almost all types of soils with sufficient moisture. It can be grown on marginal and sub-marginal rainfed soils as pure crop or inter crop (with chickpea, wheat, sunflower, potato). It is tolerant to pH in the range of 5- 7. The crop maturity cycle is between 130-150 days [76].
India being a tropical country with the abundance in linseed production should explore this valuable renewable resource for biodiesel production in addition to using it for other purposes.

Cotton

Cotton (genus: *Gossypium*) belong to family malvaceae is a perennial herbaceous shrub grown in the tropical and sub- tropical regions of the world such as India, America, Middle East and Africa [77]. Cotton also known as 'white gold' is the leading fibre crop of the world and is cultivated in the arable lands with hot and dry weather along with adequate moisture [78]. Besides fibre, cotton also serve as a feed crop for cattles. Oilcake obtained is a highly proteinous feed for livestock. While the cotton oil is used for culinary purposes and also as agricultural pesticides [79]. Cotton seed possess protein (23%), fat (20%) and crude fibre (24%). It is used as an ingredient in dairy feed formulation. After oil extraction from cotton seed, its meal is used to make cakes, flakes or pellets [80]. Cotton seed oil is considered as a potential alternative fuel for diesel engines [81]. Cotton trash when applied to animal manure composing improves its efficiency [82]. The cotton stalk have specific energy similar to that of wood and hence trash could be used for industrial fuel [83, 84].Cotton seed oil is also used in preparation of vegetable oils, margarine, soap and plastics [85]. The oil obtained from cotton has good lubricating properties and can be used as good additive to lubricating oil [86]. Cotton seed biodiesel has desirable characteristics which suit the entire engine without modification along with improved performance and emission characteristics. In one research study, it was found that B20 [indicating 20% level of biodiesel (methyl esters of cottonseed oil) and 80% conventional diesel fuel] with blend 20% yielded optimum value with less fuel consumption and higher efficiencies than diesel [87]. Yet in another study, it has revealed that the performance

parameters of compression ignition engines is improved by use of cottonseed oil biodiesel compared to diesel fuel [88]. The cottonseed oil biodiesel production requires low cost for large scale production because of lower free fatty acid and hence does not require two stage alkaline transesterification treatment. Moreover its biofuel properties are similar to that of diesel with additional benefit of high cetane number of 89.49 [89].

Globally, China is the largest producer of cotton while India is the second largest producer, consumer and exporter of cotton [79]. In India, cotton is a kharif crop or monsoon season crop and is planted from the end of April through September and harvested in winter; November- December [90]. The nine major cotton producing states of India are- Punjab, Haryana, Rajasthan (North zone); Maharashtra, Madhya Pradesh, Gujarat (Central zone); Karnataka, Tamil Nadu and Andhra Pradesh (South zone) [91]. India having a tropical wet and dry climate is ideal for cotton cultivation. Gujarat (32%) is the largest cotton producing state of India followed by Maharashtra (22%) and Andhra Pradesh (9.19%) [79]. India is the only country growing all the four species of cotton- *Gossypium hirsutum, G. arboreum* (Northern zone); *G. hirsutum, G. arboretum, G. herbaceum* (Central zone); *G. hirsutum, G. arboretum, G. herbaceum, G. barbadense* (South zone) [92]. Cotton prefers well drained soil but can be grown in a variety of soil types ranging from well drained deep alluvial to black clayey and in black and red soils. The crop is semi-tolerant to salinity and sensitive to water logging [93].

In India, cotton is a principal crop which provides employment to 6 million farmers and also engages 40-50 million people in its cultivation and processing. Minimum support price is also fixed by Government of India for its cultivation[91]. As its biodiesel production from this crop is found economic to be cultivated in large scale by research studies. So attempt should be made to produce the alternative fuel from this 'white gold' i.e, cotton.

Other plants in India with biodiesel potential

Jatropa curcas (Ratanjot) and *Pongamia pinnata* (Karanja) are oil seed bearing tree species with biodiesel potential (According to biofuel Committee, 2003) that are suitable for cultivation in fallow, waste and marginal lands of arid and semi arid regions of India. Research study on this plants showed variations among the oil content of various varieties [94]. Rapeseed, safflower, coconut are some other energy crops of India needing extensive research on the area.

CONCLUSION

India has large diversity of plant resources which has the potential for producing biodiesels. Some of them are discussed in this present review. These resources till date are cultivated only for human consumption or for other uses. Unlike Jatropa, till date these resources are not been thought for producing our valuable energy alternative i.e, biodiesel. Government of India has also approved the National Policy of Biofuel in December 2009 which encourages use of renewable alternative fuels and targeted 20% blending by biofuel by 2017. National Biodiesel Mission identified *Jatropa curcas* as suitable oilseed for biodiesel production but unavailability of high yielding draught tolerant seeds of jatropa remains major hurdles in the cultivation. India recently emphasizing 'make in India mission' launched the biodiesel programme as a part to reduce carbon emission and also import of energy from other countries (around 80%) which will help save our foreign exchange. Indian Ministry of Petroleum and Natural gas has also permitted sale of biodiesel (B100) to sectors such as railways, State Road Transport Corporation, shipping etc [95]. Road Transport Ministry of India is also setting the stage for manufacturing engines of vehicles that can ply on 100% biodiesel in the near future. As 80% of our diesel is used for transportation purposes in India, therefore use of such B100 vehicles will definitely help reduce dependence on crude oil import along with vehicular pollutions [96].

Thus these programmes emphasizes us to explore more of our natural resources like that of jatropa that exist in our country and also do more elaborate researches on such plants to get a secure future in energy and environment.

Plants discussed in this study are having huge production in India and has biodiesel yields and should be explored by extracting to understand better and for commercial application.

Conflict of interest: The authors declare that they have no conflict of interest.

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Figure 1: Sunflower with sunflower seeds

Figure 2: Castor plant with castor bean seeds

Figure 3: Soyabean plant with soyabean seeds

Figure 4: Sesame plant with sesame seeds

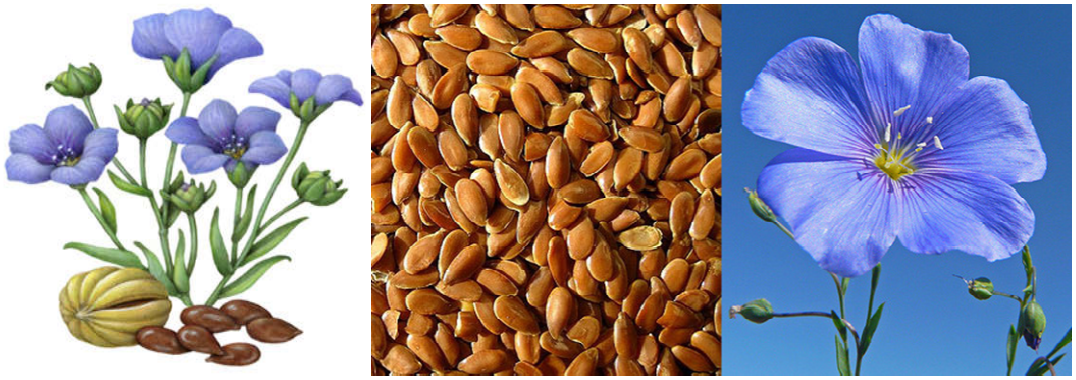

Figure5: Linseed plant with seeds and the flax flower.

Figure 6: cotton plant with cotton seeds

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