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RESEARCH ARTICLE

Ricinus cummunis: A POTENTIAL BIODIESEL PLANT FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Ricinus cummunis has been propagated as a unique plant which has potential for developing alternative source for renewable and clean energy which can replace fossil fuel use due to its high oil content. It is considered as a sole candidate in the benefits of ecology and environment because of its several merits. *Ricinus cummunis* has been advised for plantation on degraded and marginal land which otherwise a wasteland so that we can use our resources more productively. Presently, *Ricinus cummunis* has received much attention because of its potential for biodiesel production an eco-friendly fuel, biodegradable, renewable and non toxic in nature compared to petro-diesel. However, environmental and ecological benefits of *Ricinus cummunis* are not properly studied on the multiple roles. In this review several roles of *Ricinus cummunis* such as management of degraded land, potential phytoremediator, carbon sequester, use as activated carbon and medicinal uses have been discussed. Problems related to castor cultivation like toxin present in seed cake, disease incidence etc. also highlighted in the present review. Our current knowledge on *Ricinus cummunis* is not sufficient to understand its contribution in social, economic, ecological and environmental benefits. Hence, the given issues are discussed here to improve its future scope to mitigate energy crisis, environmental management and sustainable production.

INTRODUCTION

Population growth, industrialization and the regular increase in the use of fossil fuels has contributed to the advancement of environmental damage. Therefore, there is a need of clean and renewable alternative source for energy. *Ricinus communis* L. also known as castor bean is a multipurpose, fast growing evergreen shrub belonging to the plant family of *Euphorbiaceae* which has potential for biodiesel production. The true potential of *Ricinus cummunis* has not been realized but due to increase in demand for energy, price hikes in crude oil, global warming due to emission of green house gases, environmental pollution and a fast diminishing supply of fossil fuels have contribute to the search for alternative sources of clean energy. Now the conditions for its exploitation have improved considerably in recent year's (Atadashi *et al*., 2010). Castor bean (*Ricinus communis* L.) is considered as one of the most promising non-edible oil crops because of its high potential for seed production, high oil contents of seeds and its tolerance to different environmental conditions like drought tolerance (Michalis *et al*., 2011). Castor oil is a sustainable source of second generation biodiesel feedstock and the overall supply of castor oil can be increased by using different propagation technologies like tissue culture (Nahar, 2013). The plant is produced from both, seed as well as by tissue culture. Propagation by tissue culture can be used to produce a large number of plants that are genetically identical to parent plant as well as to one another (Nahar *et al*., 2012). Vanaja *et al.* (2008) have reported that its oil contents may reaches up to 50%. Its cultivation required simple technology and comparatively modest investment. The main aim of this review is to develop alternative option for clean energy production and also utilize the degraded and marginal wasteland in rural areas that will help to promote sustainable livelihoods in that region. In this respect switching from fossil fuels or other greenhouse gas emitting sources to renewable and clean sources of energy helps to improve the environmental quality around us. The cost of biodiesel is the most important aspect of promotion of *Ricinus cummunis* for biodiesel production, being eco-friendly, easy to produce raw material, easy oil extraction and transesterification.

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Geographical distribution

Castor bean was believed to have originated in Abyssinia from where it spread thousands of years ago to the Mediterranean, the Middle East and India. It is widely distributed throughout the tropics and subtropics and is well adapted to the temperate regions of the world. Today, castor is cultivated and growing in the wild between 40° south to 52° North regions. It is found upto an altitudes of about 3,000 m in areas where there is no or only slight frost. Verma *et al*. (2011) have reported that it is found throughout India and is being cultivated upto 2400 m. It is commonly found in riparian areas where it displaces native vegetation. It is also found in the abandoned fields, drainages, ditches, riverbeds and along roadsides and railroad tracks.

Ecology

Ricinus cummunis is a long-day plant, but it can adapt to a very wide photoperiodic range. Mir *et al*. (2013) reported that it can be grown on almost all soils provided they are well drained and not highly alkaline. It is distributed from cool temperate moist to wet through tropical desert to wet forest life zones. Castor requires a frost free growing period of 140-190 days. Castor bean can tolerate annual precipitation of 2.0 to 42.9dm and annual temperature of 27.8^0C. It grows best where temperatures are rather high throughout the season, but seeds may fail to set if it is above 38^0C for an extended period. It can grow in pH range of 4.5 to 8.3. Nielsen *et al*. (2011) have stated that too high air humidity increases pest and mould problems, so 30-60% humidity is considered ideal for the growth.

Genetic diversity

Ricinus cummunis is a self and cross pollinated plant. Allan *et al*. (2008) have reported low genetic diversity among *Ricinus cummunis* germplasm. Hegde *et al*. (2003) have reported that breeding for improved yield potential has being limited by a low genetic variability for productivity traits. Therefore, to increase the yield potential, it is important to maximum utilization of the desirable characters for synthesizing of any ideal genotypes. As increase in yield is the main objective of a breeder, therefore it is important to know the relationship between various characters which have direct and indirect effect on yield. Therefore, more emphasis will be given on the characters which contributes maximum to the diversity for the purpose of fixing priority of parents in hybridization program. Hence, the estimation of the amount of genetic variability, heritability and genetic advance will be necessary for yield components and to estimate the relationships among the traits.

Ecological and Environmental benefits

1. Management of marginal land

Marginal and degraded wasteland can be managed for the production of renewable energy sources as their soil quality and impoverished fertility would not be able to sustain food crops. So, the rehabilitation of dry land degraded ecosystems could be possible through *Ricinus cummunis* plantations because it is drought tolerant and can grow on degraded land. Chakarbarti and Ahmad (2008) have reported that it is cultivated as an annual crop on marginal lands and coastal sandy belts of the Indo-Pakistan region. It is nowadays growing on a wide scale on marginal and wastelands of South Asia. Joshi *et al*. (2012) have reported that castor plant is extensively cultivated in the marginal saline area of Kutch of Gujarat State of India. Castor bean can be grown on marginal and degraded wastelands which are usually unsuitable for food crops thus providing an excellent opportunity for many regions of the world to utilize their land resources more productively and provide an additional source of income (Berman *et al*., 2011).

2. Soil carbon sequestration

Soil carbon (C) sequestration by terrestrial vegetation, is one of the main approaches for greenhouse gas mitigation. Terrestrial ecosystems associated with land use and soil management play an important role in the global carbon budget (Lal, 2004). Wang *et al*. (2010) have studied that the percent of carbon retained in the residues was significantly greater by castor bean, sunnhemp and sorghum sudangrass than that by cowpea. Percent of carbon retained in the soil was greater for castor bean (72%) as compared to that for velvetbean, okra and cowpea. Various studies showed that castor bean has a good potential for carbon sequestration.

3. Potential phytoremediator

For successful phytoremediation, many hyper accumulators and accumulators plants has been screened in heavy metal contaminated soils (Zhang *et al*., 2010). Khan *et al*. (1998) considered *R. cummunis* as a hyperaccumulator and which can tolerate several heavy metals like cadmium, zinc, nickel, lead etc. consideration of all these characteristics make castor bean plant as a potential plant species for phytoremediation of heavy metals polluted soil. Olivares *et al*. (2013) found that castor plants naturally growing on mine tailings site with high concentrations of heavy metals like Zinc, Lead and Cadmium had high oil yields (41-64%) in comparison to plant growing in garden. In order to keep low prices for foodstuffs, a sustainable and efficient biomass and oil production must not proceed on otherwise valuable arable land (Schroder *et al*., 2008). Therefore, abandoned, marginal or infertile plots such as many metal-polluted sites, mine tailing represent an attractive option to grow oil-producing plants. Therefore, it has been considered as a valuable resource for phytoremediation and wasteland utilization.

4. Medicinal value

Ricinus cummunis contains many medicinal values for human and veterinary purposes. In India, the leaf, root and seed oil of this plant have been used in medicine for the treatment of the inflammation and liver disorders, Hypoglycemic, Laxative etc. (Kensa *et al*., 2011). It has been studied that stems of *R. communis* have Anticancer, Antidiabetic and Antiprotozoal activity (Singh *et al*., 2010). *R. cummunis* showed good antimicrobial activities against dermatophytic and pathogenic bacterial strains like *E. coli* (Jombo *et al*., 2008), *Shigella flexneri* (Islam *et al*., 2010). The anti inflammatory activity of *R. cummunis* was due to the presence of phytochemicals like flavonoids, alkaloids and tannins in the plant extract (Saini *et al*., 2010). Castor leaf extract has been possess insecticidal activity against *Cosmopolites sordidus* (Tinzaara *et al*., 2006) and its seed extract exhibited larvicidal activity against *Culex pipiens*, *Aedes caspius*, *Culiseta longiareolata* and *Anopheles maculipennis*.

Biodiesel production

Biodiesel play an important part in sustainable fuel and energy production solution for the future, because it is renewable, biodegradable, environmentally friendly, non-toxic, portable, readily available and eco-friendly fuel (Ahmad *et al*., 2011). The use of edible vegetable oils for biodiesel production has recently been of great concern because this may cause global imbalance to the food supply and demand, which must be raise food versus fuel debate that might cause starvation especially in the developing countries and other environmental problems caused by utilizing much of the available arable land (Atabani *et al*., 2013). This problem can create serious ecological imbalances as countries around the world began cutting down forests for plantation of oil crops. Hence, use of these feed-stocks could cause deforestation and damage to the wildlife. Therefore, due to economic and social reasons, edible oils should be replaced by non edible, lower-cost and reliable feed stocks for biodiesel production. Castor bean is one of the energy crops with high potential to provide raw material for biodiesel production. It is a non-edible, drought resistant, energy crop with high oil content, gaining attention for biodiesel production. Conceicao *et al*. (2007) have reported that biodiesel obtained from castor oil has a lower cost compared to the ones obtained from other oils because of its solubility in alcohol transesterification occurs without heating. Compared to many other crops, castor crop requires relatively fewer inputs such as water, fertilizers and pesticides. The crop can also be grown on marginal land, thus providing an excellent opportunity for many regions of the world to utilize their land resources more productively (Dokwadanyi, 2011). Biodiesel derived from castor oil rates high among other oils with ash content of about 0.02 %, sulfur content less than 0.04 %, negligible potassium content. Comparison of castor biodiesel properties with standards is shown in Table -1. Kinematic viscosity of the castor biodiesel is high but that can be reduced by neutralization and blending with petro-diesel. Other properties such as cloud point, sulphur content etc. are within the ASTM D 6751 standard limit. Biodiesel has slightly high cetane number which shows its ignition quality. Hence, the comparison from the Table-1 confirms the fact that biodiesel produced from castor oil can replace petro-diesel.

Beneficial uses

Castor seed cake can be used as animal feed and as fertilizers which not only improves the economics of *R. cummunis*, but also diversified its applications in both fuel and feed. Various uses of castor are:

1. Castor Meal and Husk for Animal Feed

Severino *et al*. (2012) have reported that meal and husks are the two major by-products in the production of castor oil. Castor cake has high protein content (~43%). Martin *et al*. (2010) have proposed that the high protein and carbohydrate content in castor seed cake can be used as a potential feedstock following some fermentation processes. The

Table 1. Comparison of biodiesel properties

Property	Castor Biodiesel	Petro-Diesel ASTM D975-98	Standard ASTM D 6751	Standards EN 14214	References
Kinematic Viscosity [mm^2/s]	10.75±0.27	1.9-4.1	1.9- 6.0	3.5-5.0	
Flash point ^0C	160±1.53	60-80	130 min	120 min	
Acid value [mgKOH/g]	0.35±0.02	-	0.50 max	0.50 max	
Cloud Point ^0C	<-13±1.00	-15-{-5}	-	-	Aldo Okullo *et al*., 2012.
Calorific Value [MJ/kg]	30.40±0.90	42-46	-	-	
Density/Specific Gravity [Kg/l]	0.88	0.95 max	o.86-0.89	-	
Cetane Number	50.64	40 min	47 min		Abdulkareem *et al*., 2012.
Total Sulphur (X-Ray) [% wt]	0.03	0.50	0.05 max	-	

transformation of castor seed cake into a non-toxic product that can be used for animal feed already has long drawn the interest of many researchers around the world, and some satisfactory results have been obtained. Nowadays, several methodologies have been developed to detoxify castor bean cake and use it as animal feed. Anandan *et al.* (2005) reported that physical processes based on heat and alkali-based chemical could detoxify castor cake. Diniz *et al*., (2010) have reported that addition of lime is the simplest but most effective method for ricin detoxification.

2. Castor Meal as an Organic Fertilizer

Castor cake is often used as an organic fertilizer as an excellent nitrogen source, fast rate of mineralization, and presenting insecticide and nematicide properties (DOR, 2004). Castor meal contained 75 g kg^{-1} of nitrogen. Kaskavalci *et al*. (2009) have reported that the addition of castor leaves and fruits to the soil enhance yield of tomato and reduced root galling and reproduction rate of *M. incognita*. Castor husks are another castor by-product that can be used as organic fertilizer. They have high potassium content (45 g kg^{-1}) but low N content (18.6 g kg^{-1}). Therefore, to provide a better nutrient balance for plant growth the husks needs to be blended with a nitrogen rich organic material (Lima *et al*., 2011). In fact, the major application of castor seed residual matter is as fertilizer.

3. Castor leaves as an adsorbent

Makeshwari and Santhi (2013) have reported that *Ricinus cumminus* leaves can be used for activated carbon preparation. Madhavakrishanan *et al.* (2010) have investigated that *Ricinus communis* pericarp carbon is very effective adsorbent of Pb (II) ions to remove from aqueous solution.

4. Other uses

Castor is important as a source of vegetable and medicinal oil and has numerous benefits to humanity. The oil has many industrial uses; it is used as a lubricant, lamp fuel, a component of cosmetics, and in the manufacture of soaps, printer's ink, plastics, fibers, hydraulic fluid, brake fluid, varnishes, paints, textile dyes, leather finishes and fungicides. Castor stems on digestion with lime yield pulps suitable for the production of straw-boards. Melo *et al*. (2008) have reported that ethanol can be produced from castor meal by acid or enzymatic hydrolysis.

Yield

India is the world's largest producer of castor seed with an annual production of 590 × 106 kg. MT (Lima *et al*. (2011). India accounts for nearly 60% of the world's production of castor (FAOSTAT, 2006) as shown in Table-2. The average yield of castor seed is 1250 kg/hectare and oil yield is 550 lit/hectare. India is the world's largest producer and exporter of castor oil. It is currently cultivated mainly in Gujarat and Andhra Pradesh under rain fed conditions. Castor is a drought tolerant plant, but seed yields are reduced under limited water availability. Therefore, only with an adequate water supply seed yield can be optimized, particularly with genotypes with high yield potential. Raj *et al*. (2010) have reported that seed yield of 3780 kg ha^{-1} was obtained in India with the hybrid GCH-5 under condition of adequate water supply. Seed yield can be increased by adding required fertilizers in the soil. Sahrawat *et al*. (2010) have studied that seed yields were increased an additional 15% when Nitrogen and Phosphorus were also applied to castor field.

Table 2. The total seed production of Castor

Country	Production area (ha)	Total Production(MT)	Reference
India	805,000	861, 000	
China	255, 000	861, 000	
Brazil	184, 231	130, 565	FAOSTAT,
Ethiopia	14, 500	15, 000	2008.
Thailand	13, 430	10, 492	
Paraguay	10, 000	11, 000	
World	1369, 720	1314, 193	

Constrains and problems

It is important to keep in mind that despite of the several advantages that support the *Ricinus cummunis* cultivation for biodiesel production but simultaneously there are also some problems which are discussed below:

1. Castor seeds as toxin

Godoy *et al.* (2009) have studied that castor seeds contains a strong toxin ricin, a toxic volatile alkaloid ricinine and an allergenic protein fraction. The castor seeds contain approximately 0.2% of the alkaloid. In experimental mouse models ricinine causes hyperactivity, seizure and subsequent death due to respiratory arrest (Worbs *et al*., 2011). Allergens are an important concern for all who handle castor seed or meal in storage and oil extraction facilities (Severino *et al*., 2012). Deus (2011) have reported low molecular proteins, 2S albumins, as the main allergenic compounds in castor plant.

2. Diseases incidence

R. cummunis will be affected by several diseases; however, only a few are regarded to be of economic importance. The three major diseases which affect castor are: gray mold, vascular wilt and charcoal rot. These disease can be managed by use of varietal resistance, seed treatment, and crop rotation. In India, several commercial hybrids and breeding lines resistant to vascular wilt have been developed (Patel and Pathak, 2011). Breeding programs for castor plant have failed to develop, disease resistant genotypes, but genotypes with moderate levels of tolerance have been identified (Anjani, 2012).

3. Pests

In India, insect pests that severely affect castor are semilooper (*Achaea janata*), castor shoot borer (*Conogethes punctiferalis*), capsule borer, *Spodoptera litura*, red hairy caterpillar (*Amsacta spp*.), and leafminer (*Liriomyza trifolii*) (Anjani *et al*., 2010). In Brazil, the major pests are stink bug (*Nezara viridula*), leafhopper (*Empoasca spp.),* defoliators including armyworm (*Spodoptera frugiperda*), *A. janata* and *Agrotis*

ipsilon and the mites *Tetranychus urticae* and *T. ludeni* (Riberio and Costa, 2008).

Conclusion

Ricinus cummunis is a non-edible high oil yielding plant which can be grown on marginal and degraded land. *R. cummunis* has low nutritional requirements so it is well adapted to the marginal soils, but in order to support a high biomass production, the crop required desired inputs in terms of irrigation and fertilizers. It shows good potential for phytoremediation of heavy metal polluted soil so it can be grown on mine tailing land. The establishment of *R. cummunis* plantation on the degraded land will lead to carbon sequestration and helps to improve the soil quality and also serves as a source of income from the unutilized and degraded land. Castor oil is used in many industrial products like paints, grease, waxes, fly paper, typewriting and printing inks etc. castor oil has a good potential for biodiesel production. Biodiesel from castor oil is an attractive alternative for sustainable and renewable energy production. During biodiesel production many valuable by-products like castor meal, husk and glycerol are produced. Castor meal and husk can be used as organic fertilizer and also as a feed for animals after detoxification. *Ricinus cummunis* plantation should not be considered yet as a highly profitable cash crop unless the value of by-products and other advantages are duly recognized. Furthermore, *R. cummunis* biodiesel offers environment friendly development with economic and ecological advantages that includes lowering of green house gases emission and decreasing the dependency on fossil fuel. Multiple benefits of *R. cummunis* can be achieved by future critical research efforts to provide new impetus for local and regional sustainable development.

Recommendations and future prospective

In view of the above discussion to support the extension of castor cultivation on marginal and degraded wastelands, needs to develop new varieties and hybrids, which can produce high seed yield and have high oil content. There is also need to develop hybrid species which have fewer toxins. This would allow the seed cake to be used as animal feed reduce the risks to human health. New technologies required to use the by-products more efficiently which provide additional value for promotion of castor cultivation. Castor seed cake also has potential for biogas and ethanol production but very less research work has been done in this field. Therefore, need to explore potential of seed cake for biogas and biodiesel production through critical research work. Integrated agro-technologies should be applied to enhance castor seed yield by using agronomic practices such as tissue culture, standardization of optimum plant density, use of growth hormones, nutrient management and irrigation practices.

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