Multifarious Uses of Castor (*Ricinus communis* L.)

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Article History

Article ID: IJEP199
Received in 24th September, 2017
Received in revised form 18th October, 2017
Accepted in final form 2nd November, 2017

Abstract

Castor (*Ricinus communis* L.) bean plant has diversified uses as various parts of it can be used in agriculture, industry, medical, and ornamental fields. It is an ideal candidate for production of high value, industrial and oil feed stocks, which was due to high oil (48−52%) and recinoleic acid (85-90%) contents. Its' unique fatty acid composition allows oil to provide economically competitive feed stocks needed for production of premium quality biodiesel, short chain aviation fuels, fuel lubrication additives and high value biopolymers. Further, various parts of castor plant and oil are used against eye infection, liver disorders and sexually transmitted diseases. Castor cake finds application in Agricultural fields as a nutrient source. Its' leaf can be used for feeding eri silk worms in ericulture. An attempt was made to document innumerable uses of castor across various sectors as it was not done earlier. The articles discusses future of this crop in the light of increasing demand for ricin free castor besides expanding area and need for enhancing productivity.

Keywords: Biofuel, castor, diversified uses

1. Introduction

Castor (*Ricinus communis* L.) belongs to the Euphorbiaceae family. It is the sole species in the monotypic genus, *Ricinus*, and subtribe, *Ricininae*. Both *Ricinus* and *communis* are Latin words. It is commonly known as castor oil plant and is a soft wooden small tree developed throughout tropics and warm temperature regions. It is believed to have originated from Ethiopia (Africa) and India. At present, castor is cultivated across 30 different countries, of which India, China, Brazil, Mozambique, Ethiopia and Thailand are the major ones accounting for about 90% of the worlds' production. India accounts for nearly 66.5 and 82.9% of world's castor area and production, respectively. Completion of Draft genome sequence of castor bean plant has been a successful story at the end of last decade. Unravelling the genetic information of this multifaceted crop is a boon for us to further exploit its economic value (Ramprasad and Bandopadhyay, 2010). Castor plant parts have immense medicinal value, while castor oil has wide industrial applications. As all parts of the plant in one or other way can be used for productive purposes, it is called as *Kalpvriksh* (means tree of gold and precious stones) (Ramanjaneyulu et al., 2013). The multifarious uses of castor and oil are enumerated below.

2. Agricultural Uses

2.1. Organic nutrient source

Castor cake is a by-product of milling industry and account for 60% of crushed seed. Despite containing 30-40% protein which contains ideal amino acid profile with cysteine, methionine and isoleucine, however, it is not safe as animal feed due to presence of toxic compounds such as ricin, allergin and ricinine (Prasad, 2010). It is considered as rich source of concentrated organic manure as it contains 6.6%N, 2.6% P_2O_5 and 1.2% K_2O (cake from decorticated seed) and 4.5% N, 0.7% P_2O_5 and 1.9% K_2O (cake from undecorticated seed) and can be applied to Agricultural fields. It is mostly used for sugarcane fields as this cake is not attacked by white ants (Ramanjaneyulu et al., 2013). About 100 kg of castor cake will supply nitrogen equivalent to that of 1800 kg of cow dung thus potential source for organic farming. Further, it can be applied to any type of soil. It encourages soil microbial activity, promotes root development and winter cold hardiness.

Castor cake should be applied at least three weeks before sowing of the crop and field has to be kept moist for degradation of the toxicants. Application of castor cake can also be helpful in reducing the cost of phosphatic fertilizer (Gupta et al., 2006). Kolay (2007) observed yield response up

to 6.57 t ha^{-1} when castor cake was applied to sugarcane crop @ 90 kg ha^{-1} in Bihar. In pot experiment on melons, Azim et al. (2011) reported 100% suppression of root knot nematode and soil larvae population due to application of argan/ castor cake and both these cakes were effective than neem cake. However, melon biomass declined due to castor cake application as a result of phytotoxicity. As the toxicity makes it unsuitable for use as animal feed, it results in a lower price for the meal while compared with prices of competing oilseed-meals such as soya meal. This combination of high fertilizer value and low price has resulted in an ever increasing demand for castor meal from the organic fertilizer market worldwide (Prasad, 2010). Castor stubbles and shelled capsules can be incorporated in to the soil, which on decomposition can add organic matter to the soil. Otherwise, they can also be utilized in the preparation of compost or vermicompost which in turn can be applied to agricultural fields to improve the soil fertility. The leaf fall of this plant contributes both as surface mulch and as a source of nutrition (Sudhakar Babu, 2010)

2.2. Biogas generation

Biogas is produced by anaerobic digestion through anaerobic bacteria or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops by the breakdown of organic matter. It is a renewable source of energy and can be produced from locally available raw materials. Further, it is socially acceptable and environmentally friendly gas. It mainly contains methane (50-75%), carbon dioxide (25–50%) and small amount of nitrogen (0–10%), hydrogen (0–1%), hydrogen sulphide (0–3%), moisture and siloxanes with no oxygen (Richards et al., 1994). It can be used as a fuel for cooking at domestic level or running small scale industries. Besides, it can also be used to convert the energy in the gas of a gas engine into electricity. In some countries, like UK, biogas is estimated to have the potential to replace around 17% of vehicle fuel.

The use of castor cake in biogas generation resulted in maximum digester microbiological activity and gas output (Lingaiah and Rajasekaran, 1986). It has been found that methane content of biogas generated from non-edible oil cakes is 70% and is higher than that produced from cowdung (55-60%). Further, they have estimated and reported that biogas produced from non-edible castor oil cake is much superior in terms of gas yield (0.4–0.5 m^3 kg dry $matter^{-1}$), volumetric efficiency (2.0–2.5 lit day^{-1}), methane content (70%) to animal manure based biogas (0.18; 0.5–0.7; 55–60%).

2.3. Ericulture

The term 'Ericulture' is derived from the word 'eri' meaning castor and culture meaning cultivation. So, rearing of eri silkworms on castor leaves for obtaining 'eri silk' is called as poor man silk. Ericulture has been proved to be an ideal subsidiary occupation providing gainful supplementary income to a large number of rural and tribal populations. It provides ample scope for employment and income for the survival of those people without much capital and other scope. Being a labor intensive activity, it acts as a solution to the problem of unemployment and reduction in poverty (De and Das, 2007). Benchamin and Jolly (1987) also identified ericulture as an occupation of "low investment and high output". This enterprise provides ample opportunity for sustainable dry land based farming system for higher income generation. The most important fact is that ericulture goes well with dry land farmers, especially in tribal region. On an average, three crops can be taken up against the single harvest in other dry land crops, which would be sufficient to maintain a family through additional income. Considering the advantages of ericulture, many state governments in the north east and south India has initiated steps to popularize eri culture (Rama Lakshmi, 2012).

Traditionally ericulture has been practiced in north eastern states in India on uncultivated or wild plants of castor (*Ricinus communis)*, kesseru (*Heteropanax fragrans*) and barkesseru (*Ailenthus* sp.), payam (*Evodia flaxinifolia*) and tapioca (*Mainhot esculentum*). However, castor is the most important food plant for eri silk worm due to its' good palatability, good quality of cocoon, easy availability of castor leaf because of its' commercial cultivation for non-edible oil. But it is less preferred in summer because of increase in leaf phenolic content. Castor leaves can be used for feeding eri silk worms in ericulture. Research results revealed that 30% defoliation is permissible and the same can be used in ericulture without foregoing economic yield. Besides, the farmers can be benefitted with an additional income upto Rs. 6000 to 7500 ha^{-1} through ericulture which is a boon for rainfed castor growers. Further, eri pupae is very much relished by tribal people and is considered at par with mutton or chicken (Saratchandra, 2010). The neutral lipid of silkworm pupae (*Bombax mori* L.) is a good source of alpha linolenic acid (ALA), an essential fatty acid. Such poly unsaturated fatty acid (PUFA) is known to have positive effects on several risk factors associated with coronary heart diseases. Due to presence of linolenic acid to the tune of 43% in eri pupal oil, it is considered as a good source of omega 3 fatty acid (Prasad, 2010; Shankar et al., 2006).

2.4. Pest control

Castor plants can be used as a trap crop for pest control in groundnut. This helps in reducing the cost of spraying as pesticides and will be sprayed only on castor plants when they are affected by *Spodoptera* sp. The diversity in waxy bloom on leaf, stem and capsule and variation in capsules spines attributed to certain pest and disease tolerance. E.g. triple bloom castor types are tolerant to leaf hoppers but susceptible to whiteflies, while, single bloom castor is resistant to whiteflies but susceptible to leaf hoppers. On the other hand, double bloom castor types are placed in between the single and double bloom types with regard to whitefly and leaf hopper incidence. Extract of *Ricinus communis* exhibited acaricidal and insecticidal properties against the adult of *Haemaphysalis bispinosa* Neumann (Acarina: Ixodidae) and hematophagous fly *Hippobosca maculata* Leach (Diptera: Hippoboscidae) (Zahir et al., 2010). Coffee beans are

treated with a mixture of castor and groundnut oils by the malayali tribes of shervaroys to control storage pest in coffee (Mohapatra et al., 2009). Castor cake when applied to the soil, protect the plants from soil nematodes, insects, and parasites by acting as a natural repellant. The oil is often used in the USA to repel moles and voles in lawns. The population of plant-parasitic nematodes, *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Tylenchorhynchus brassicae*, *Helicotylenchus indicus*, etc., and the frequency of the pathogenic fungi *Macrophomina phaseolina*, *Rhizoctonia solani*, *Phyllosticta phaseolina*, *Fusarium oxysporum* f. *ciceri*, etc., significantly reduced in chickpea and wheat fields due to application of castor cake (Tiyagi and Mashkoor, 1995).

2.5. Storage

In India, Pakistan, Nepal and Bangladesh, food grains are preserved by applying castor oil. It helps to avoid rotting of grains of rice, wheat, and pulses thus extends longevity of stored grain. In the food industry, castor oil (food grade) is used in food additives, flavorings, candy (*e.g.*, Polyglycerol polyricinoleate in chocolate) (Wilson et al., 1998) as a mold inhibitor and in packaging.

3. Industrial Uses

Seed is the most important economic product of castor crop. The castor seed contains 48-52% oil and has tremendous industrial value. The oil is a colorless to very pale yellow liquid with mild or no odor or taste. It is a renewable resource and biodegradable. It is highly stable oil as it boils only at 313°C (595 °F) and doesn't freeze even at low temperature. Its density is 961 kg m^{-3} (Aldrich, 2003). It has high acetyl or hydroxyl value, high specific gravity (0.958 to 0.969), high refractive index at 25°C (1.477 to 1.487), strong dextra rotatory nature (+7.6 to 9.7) but low saponification (179 to 187) and iodine value (82-90). This oil is unique in its chemical composition and is a triglyceride in which approximately 90% of fatty acid chains are hydroxyl (ricinoleic acid) in nature. Castor oil is the only source of ricinoleic acid. It is a mono unsaturated, 18-carbon fatty acid. It is an unusual fatty acid as it has hydroxyl functional group on the 12th carbon. This functional group causes ricinoleic acid (and castor oil) to be more polar than most fats. Industry uses 600-800 million pounds of castor oil per annum.

3.1. General uses

Use of castor oil and its' derivatives has been in vogue in many industrial applications especially in lubricants, fuel additives, hydraulic and brake fluids, pharmaceuticals, cosmetics, paints, dyes, coatings, inks, cold resistant plastics, waxes and polishes, pharmaceuticals and perfumes. Further, it can be used for production of hydraulic fluid, artificial leather, printing ink, rubber, recinol, soaps and greases (Ogunniyi, 2006). Other uses include paints, varnishes and polymers, nylon 11 plasticsrecinol, lubricating and heavy duty automotive greases, telecom engineering plastic, printing ink, recinol, lubricating and heavy duty automotive greases (Azambuja et al., 2006; Ogunniyi, 2006), refrigeration lubricants, rubbers, sealants, textiles, washing powders, and waxes. Since it has relatively high dielectric constant (4.7), highly refined and dried castor oil is sometimes used as a dielectric fluid within high performance high voltage capacitors. Castor oil due to its high viscosity can be used for conversion into biodiesel too. Its' biomass can also be used to generate energy through gasifiers (Sudhakar Babu et al., 2013).

3.2. Lubrication

Most of the vegetable oils can be considered as attractive alternatives to petroleum derived lubricants mainly owing to their good lubricity and biodegradability nature, but, oxidative stability and low temperature performance limit their widespread use. Castor oil maintains higher viscosity even at high temperatures and liquid at low temperatures. Due to its' non-drying nature, it is regarded as one of the best lubricants. Hence, it is extensively used in the manufacture of lubricants. The production of lithium grease consumes a significant amount of castor oil. Hydrogenation and saponification of castor oil yields 12-hydroxystearic acid which is then reacted with lithium hydroxide or lithium carbonate to give high performance lubricant grease. In fact, railways used castor oil for lubrication before 1914-1918. Now, castor oil is widely used as a lubricant in jet, diesel and race car engines (Mc Guire and Nancy, 2004). The viscosity of castor oil at 10°C is 2,420 centipoise (Brady et al., 1997). However, castor oil tends to form gums in a short time and its use is therefore restricted to engines that are regularly rebuilt (eg. race engines). Infact, castor oil was the preferred lubricant for rotary engines after engine's widespread adoption for aviation in Europe in 1909. The methanol-fuelled two-cycle glow plug engines used for aero-modelling have used varying percentages of castor oil as a dependable lubricant.

3.3. Derivatives

Castor oil is the raw material for the production of a number of chemicals, notably sebacic acid, undecylenic acid and nylon-11. Castor oil is used in the preparation of sulphonated castor oil, known as Turkey oil by adding sulfuric acid to vegetable oils like castor oil. It is inturn used in cotton dyeing, printing and leather industries. It was the first synthetic detergent after ordinary soap. Castor oil can be used in the manufacture of soaps as it gives a certain degree of transparency to soaps and shining and silky appearance to jute fabrics.

The following are the important derivatives which are being exploited for variety of applications.

- Nylon 11, engineering plastic (the largest single use of the oil)
- Hydrogenated castor oil (lubricants, greases and additive in variety of formulations)
- Dehydrated castor oil and its acids (coatings, inks, sealants and related products)
- Sebacic acid (component of Nylon 6,10; esters as aircraft lubricants and plasticizers for vinyl films including food wrap)
- Ethoxylated castor oil (industrial uses in surfactants,

emulsifiers, lubricants in textile, coatings and cosmetics)

- Sulfonated (sulfated) castor oil (as surfactants, lubricants)
- Polyurethane encapsulants (electronics and telecommunications, coatings)
- Alkyl Esters (cosmetics, plasticizers, lubricants)
- Oxidized or polymerized castor oil (coatings, inks sealants)
- Castor oil without modification in polymers, rubbers, cosmetics, inks, coatings and a wide variety of industrial compounds
- **C11:** It is obtained by pyrolysis of castor oil or its methyl ester. It is converted to PA-11 through a series of processes. Derivatives of C11 acid (Undecylenic acid) are used primarily for antifungal properties.
- **C7:** Jasmine is the aroma related C7 aldehyde. It is used in washing powders, soaps, candies and other perfumes
- **C7 acid:** It is used as lubricant, to improve the weedicide properties,
- Dehydrated castor oil is used for conversion to Sebacic acid, an important ingredient for the synthesis of Nylon fibre. Sebacic acid is obtained by alkali fusion of castor oil producing 2-octanol as the co-product.

3.4. Biodiesel

Biodiesel, an alternative diesel fuel from vegetable oils and animal fats is biodegradable, non-toxic with low emission profiles thus proven to be an environmentally friendly fuel compared to petroleum diesel (Meher et al., 2006). Demand for biodiesel has been increasing due to rise in the petroleum prices during the last few years. Support policies by governments in different countries like Europe, Brazil, Namibia and India gave a fillip to the use of biodiesel fuels for transport like the EU Directive 2003/30/EC in Europe (Vicente et al., 2007). The National Mission on Biofuels in India targeted to achieve 20% blending of biodiesel (B20) by 2012 with an aim of bringing 4,00,000 ha of marginal land under cultivation of non-edible oilseed crops mainly Jatropha (Lavanya et al., 2012). However, castor is a viable alternative to Jatropha due to its shorter growing period, availability of standard agronomic practices for assuring good yields, good yield potential of 1500 to 1800 kg ha^{-1} in rainfed conditions and 2500 to 3000 kg ha^{-1} under irrigated dry conditions and 3500 to 4000 kg ha^{-1} under drip irrigation and early maturity within 150 to 210 days after sowing (Hanumantha Rao et al., 2003; Lavanya et al., 2006; Lavanya and Mukta, 2008; Pathak, 2009). Further, after the reproductive phase begins, the castor plant is able to continually initiate new racemes and produce seeds (Severino and Auld, 2013). The non-edible seed and hardiness of the crop with high oil yield potential make it suitable for biofuel programmes in waste lands (Sudhakar Babu, 2010).

4. Medicinal Uses

India has a history of using different plants in its indigenous systems of medicine (Ayurveda, Unani and Siddha) that dates back to 5000 years. Ayurveda records over 8000 herbal remedies. About 6000 plants were used in traditional, folk and herbal medicines in India (Huxley, 1984). Different parts of the plant or oil from castor can be used as a base material in most of the medicinal treatments. E.g., the leaf can be used in the treatments related to antiviral, biliousness, burns, ear/head ache, malaria and night blindness while stem is used for treatment of cancer and hypoglycemia. The flowers can be utilized against glandular and vaginal pain. Fruits are used for curing tumors, treating piles, liver and spleen diseases. Root bark is used as purgative, in abortion, ascites, asthma, bronchitis, carination (expulsion of gas from stomach and intestines), hypoglycemia, leprosy, pains, rectum and rheumatism diseases (Borthakar, 1981).

4.1. Eye infection

Conjunctiva is a thin and delicate membrane that covers the eyeball. Conjunctivitis is the inflammation of the conjunctiva, characterized by redness and often accompanied by a discharge. It is a common eye problem when eyes are exposed frequently or continuously to microorganisms and environmental conditions that can cause infections or allergic reactions. It can be acute or chronic depending on severity of symptoms and the type of organism or agent involved. It can be very easily transmitted to others during close physical contact, particularly among children (Prewitt, 2004). Leaf decoction of *Achyranthes aspire* mixed with castor oil can be applied on the head and body an hour before head bath to overcome the problem of conjunctivitis.

4.2. Skin diseases

Eczema or atopic dermatitis is a form of chronic inflammation of the skin characterized by redness, itching and oozing vesicular lesions (Armstrong and Johnson, 2011; Bershad, 2011). Other symptoms include skin edema (swelling), itching and dryness, crusting, flaking, blistering, cracking, oozing or bleeding (Johannes et al., 2006). Powder of Indian birthwort (*Aristolochia indica*) along with the oil prepared from boiling *Datura stramonium* leaf juice is mixed with castor oil and is applied on the skin against eczema.

Filariasis is a parasitic and infectious tropical disease caused by filarial nematode worms and is transmitted by mosquito bites. The most spectacular symptom is elephantiasis - edema with thickening of the skin and underlying tissues. It affects mainly the lower extremities, while the ears, mucus membranes and amputation stumps are affected less frequently. Castor seed paste is applied on effected part (feet) against filariasis.

Castor oil is mixed with copper sulphate and is used to treat various skin ailments. Pounded leaves of *Alangium salvifolium* are mixed in castor oil and bandaged on the affected part of inflammation. Psoriasis is a chronic skin disease characterized by dry red patches covered with scales and it occurs especially on the scalp, ears and genitalia and the skin. The leaf of *Aristalochia bracteata* along with the rhizome of *Curcuma domestica* and seed of *Piper nigrum* are mixed with cow urine

and made into a paste and boiled in castor oil. Such mixture is to be applied on the affected part of psoriasis regularly.

4.3. Liver disease

Jaundice is yellowing of the skin and eyes and occurs due to presence of too much bilirubin in the human body. Bilirubin is a yellow pigment which is formed due to breakdown of dead red blood cells in the liver. Jaundice is an indication of malfunctioning of liver, gallbladder, or pancreas. Tender castor leaf paste along with coconut water is orally administered to the patients suffering from jaundice.

4.4. Sexually transmitted diseases (STDs)

STDs are also known as sexually transmitted infections (STI) and are transmitted between humans by means of sexual behavior. Some are transmitted due to reuse of drug needles after their use by an infected person, through childbirth or breastfeeding. Castor oil packs will improve White and red blood cell (WBC and RBC) count within two weeks thus improves the immune system in human body. Castor oil with arsenics and copper sulphate are used in the treatment of syphilis and gonorrhea. Though no. of drugs exist that can improve lymphatic flow, this task can easily be performed by topical application of castor oil. When castor oil is absorbed through the skin, the lymphocyte count of the blood increases. This is a result of a positive influence on the thymus gland and/or lymphatic tissue. The flow of lymph increases throughout the body which inturn speed up the removal of toxins and reduces the size of swollen lymph nodes resulting in overall improvement in organ function.

4.5. Miscellaneous

Castor oil is a well-known general laxative useful in treating painful defecation called constipation. In rural areas, small quantity of castor oil is given to children's suffering from constipation which facilitates bowel movement.

Warm leaf paste of castor plant is applied on the forehead to cure head ache. Leaf juice of *Eclipta prostrata* is mixed with castor oil and applied on the head to reduce the problem of dandruff. Leaf extract of *Abrus precatorius* boiled in equal quantity of castor oil and is applied to hair regularly for proper hair growth. Mixture of fruit juice of *Gmelina asiatica* and castor oil is boiled and used as hair tonic for better hair growth.

Paralysis is the sensory loss of muscle function. A table spoon of ash obtained by burning the castor leaves is mixed with honey and given as diet to the affected patients (Kavita et al., 2010). Castor oil ground with niger seed is applied externally to cure piles and fistula. Rheumatism or rheumatic disorder is a non-specific term for medical problems affecting the joints and connective tissue. Crushed leaves of *Cardiospermum halicacabum/Calotropis gigantea/Delonix alata* along with castor oil are bandaged on the tumours and rheumatic swellings.

Ricinoleic acid has been shown to be effective in preventing the growth of numerous species of viruses, bacteria, yeasts and molds. This will explain high degree of success in the topical use of the oil for treating ailments such as ringworm, keratoses (non-cancerous, wart-like skin growths), skin inflammation, abrasions, fungal-infected finger and toe nails, acne and chronic pruritus (itching). The concerned area has to be simply wrapped with castor oil soaked cloth or band-aid.

Therapeutically, modern drugs are rarely given in a pure chemical state. Most of the active ingredients are combined with additives. Castor oil or a castor oil derivative such as Cremophor EL (polyethoxylated castor oil, a non-ionic surfactant), is added to many modern drugs including

- Miconazole, an antifungal agent (Fromtling, 1988)
- Paclitaxel, a mitotic inhibitor used in cancer chemotherapy (Micha et al., 2006)
- Sandimmune (cyclosporine injection, USP), an immunosuppressant drug widely used in connection with organ transplant to reduce the activity of the patient's immune system (Zhang et al., 2001)
- Saperconazole, a triazole antifungal agent (contains Emulphor EL-719P, a castor oil derivative) (Sugar et al., 1994)
- Tacrolimus, an immunosuppressive drug (contains HCO-60, polyoxyl 60 hydrogenated castor oil)
- Xenaderm ointment, a topical treatment for skin ulcers (a combination of Peru balsam, castor oil and trypsin) (Beitz, 2005)

5. Ornamental Uses

Castor plant is used extensively as a decorative plant in parks and other public areas, particularly as a "dot plant" in traditional bedding schemes. Some of the *Ricinus communis* varieties are used for ornamental purposes and they include *Gibsonii* (red tinged leaves with reddish veins and pinkish green seed pods), *Carmencita* Pink (with pinkish red stems), *Carmencita* Bright Red (red stems, dark purplish leaves and red seed pods (Phillips and Martyn, 1999), '*Impala'* (compact, only 3.9 feet tall with reddish foliage and stems, brightest on the young shoots, '*Red Spire'* (6.6-9.8 feet tall) with red stems and bronze foliage, *'Zanzibarensis*' (6.6-9.8 feet tall with large, mid-green leaves) that have white midribs (Christopher, 1996). The attractive castor seeds are used in jewellery, mainly necklaces and bracelets.

6. Summary and Future Perspectives

The castor plant has been proved to be a versatile and unique non-edible oil plant with diversified uses in Agriculture, industry and medicine. There is a huge demand for castor oil for its use in biofuel programmes across the world due to implementation of Kyoto Protocol norms of the UNO in reducing global emissions of GHGs. However, upcoming of alternate remunerative crops like Bt cotton and maize across the castor growing zones in India have pushed the castor to the backstage. However, keeping in view wide array of uses of castor plant, there is s a need to conserve germplasm and promote the crop on a large scale. There is a need to improve

area, production and productivity of castor by expanding the crop to new niches like non-traditional areas, rice fallows, post monsoon season and also to the areas with irrigation water shortage and persistence of wild boar problem. Besides, site specific land configuration and management strategies for effective soil and moisture conservation in dry lands and adoption of micro-irrigation methods will certainly help improve the productivity.

Reduction of ricin or production of ricin free castor besides increasing recinoleic acid should be the flagship programme for near future. Transgenics should be employed to find out ways and means for controlling Botryotinia gray rot (*Botrytis ricini*) which is responsible for poor yield and oil quality. Augmentation of trait specific germplasm, prebreeding and genetic enhancement, allele mining, functional genomics, proteomics, metabolomics, marker assisted selection (MAS) and gene pyramiding area to be deployed to solve biotic and abiotic stresses with a view to improve productivity and oil quality. With the distinct possibilities of use of castor oil as biojet-fuel and biolubricants through biotechnological interventions, the opportunities for castor production and use are unlimited. Indian must strengthen research and development efforts on all aspects of castor including value addition on priority to exploit and sustain the benefits of revolution in castor production.

Inter institutional linkages must be established among Indian Institute of Chemical Technology (IICT), Indian Council of Agricultural Research (ICAR), Solvent Extraction Association of India (SEAI) and private industries to work in tandem with each other to strengthen value addition sector through innovative action plan. Central government in India should facilitate value addition on a large scale through favourable policy framework. So that India can maintain monopoly status not only in production and productivity but also in the export of value added products.

7. Conclusion

The seeds, other parts of castor bean plant and by products of its' oil are widely used for different purposes in various fields as discussed. However, the technology required to produce innumerable no. of derivatives from castor oil is lacking in India due to which the country is relying on other countries inspite of being a global leader in area, production and productivity. Further, market rate for castor seed has to be enhanced in tune with the other crops keeping in view the ever increasing global demand for seed and oil.

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