Mysore J. Agric. Sci., 54 (2) : 14-29 (2020)

An Overview of Utility, Status, Retrospective and Prospects of Castor : A Review

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ABSTRACT

India has quadrupled the castor production during recent past and figured as a global leader in castor production. Presently, castor is being cultivated in an area of 0.83 million hectare and producing 1.57 million tons with the average productivity of 1.90 tons per hectare in India. Mozambique, Brazil, China and Angola are the countries which are having sizable area under castor production. India is earning an export revenue of 10,692 crore rupees with the annual export of 10. 92 million tons, while, China, Japan, South Korea, France, UAS and European Unions are the true borrower of Indian castor. If the present trend of demand propagates further, India is responsible to produce an additional castor with the worth of 270.24 million rupees by 2025 as it is having multifarious industrial utilization in automobile, pharmaceutical and aviation sector, which describes the demand of castor in domestic and global market. On the other hand, area under castor is decreasing gradually over the years. During 1990 area under castor was 0.8 million hectares. Whereas, by very next decade, area under castor fell down to 0.7 million hectares and again gradually increased to 0.73 by 2009-10, at present it occupied about 1.14 million hectares of farm land. In spite of fluctuations in area under cultivation, production and productivity are showing increasing in trend; it could be due to technological advancement in castor. The initial efforts on crop improvement was activated as early as 1920-1930, however, real break through happened during late 1960s through development of short duration variety 'Aruna'. Subsequently due to continued efforts, at present castor genotypes with yield levels of 1.5 to 1.8 tonnes and 3.0 to 3.2 tonnes per hectare, respectively in rainfed and irrigated ecosystem are under cultivation. Even if development of several proven technologies over the period of time, an exploitable yield reservoirs of castor in India is about 70 per cent, just mere bridging this gap in yield, production could be increased from existing 15.7 lakh tons to 17.95 lakh tones in near future. Despite huge difference between realizable and actual yield, castor is the only oilseed crop exhibiting highest positive annual compound growth rate in area (+11.10), production (+27.00) and productivity (+16.00) over rest of the eight cultivated oilseed crops of India.

Keywords: Castor, Export, Hybrids, Oilseed, Prospects, Retrospect, Yield

CASTOR (*Ricinus communis* L.) an indeterminate type of C_3 plant belongs to *Euphorbiaceae* family. Among the nine cultivated oilseed crops, castor is the most important non-edible oilseed crop with immense industrial potentiality. The crop is being grown across the world in tropical, sub-tropical and warm temperate regions. Castor oil is having diversified applications as it is non-edible and has been used almost entirely for pharmaceutical and industrial usages ranging from medicines, aviation fuels, fuel additives, biopolymers and biodiesel (Prasad, 2012). Castor oil is the only natural source of a hydroxylated fatty acid which is containing around 90 per cent of the ricinoleic acid; no other vegetable oil produces such a high predominance of a single fatty acid. Castor oil industry expects low variability in the fatty acid profile (Mutlu and Meier, 2010) and it appears to be a very low influence of production environment on concentration of *ricinoleic* acid in castor. The high viscosity over a wide range of temperatures makes castor oil certain characteristics of castor oil derivatives like high lubricity, high melting point and insolubility in aliphatic petrochemical fuels and solvents make it useful as a lubricant for equipment operating under extreme conditions (Yao *et al*., 2010). Hence, castor oil is popularly called as 'Super Lubricant'. Mutlu and Meier (2010) opined that 'castor oil is one of the most promising renewable raw materials for the chemical and polymer based industries due to its manifold uses and to a series of well established industrial procedures that yield a variety of different renewable platform chemicals'. Important groups of products containing castor oil are oil based formulations of lubricants, grease, functional fluids, process oils, oleochemicals, reactive components for paints, coatings, inks, polymers, foams, textile finishing agents, emulsifiers, stabilizers and wetting agents (Mutlu and Meier, 2010). Further, Johnson (2007) enlisted a broad group of castor derivatives considered safe as cosmetic ingredients. Apart from industrial importance, castor oil is an indispensable ingredient of vast group off ayurvedic and naturopathic treatment, the cake left out after extraction of oil is extensively used as organic manure. *Eri* is a special group of host specific silk worm breed which feeds on castor leaf and is an integral part of farming activities of north eastern states of India.

India is the world's largest producer-cum-exporter of castor contributing to more than 85 per cent of world's total production and dominating the global trade with a share of more than 90 per cent. Currently, India produces around 1.57 million tonnes of castor seed; it meets more than 80 per cent of the demand of castor oil, thereby enjoying a dominant position in the world castor scenario (Anonymous, 2018b). In India, commercial cultivation of castor is taking place in 16 states. Among them Gujarat, Rajasthan, Haryana, Telanagana State and Andhra Pradesh are the major states contributing about 91 per cent and 97 per cent to the countries area and production respectively (Anonymous, 2019).

Gujarat is a small geographic region in India, where the global production of castor oil is concentred. Factors such as subtropical climatic conditions and labour-intensive cultivation methods are favouring the cultivation of castor seed. Approximately 73 per cent of the castor oil produced in India is concentrated in Gujarat itself (Anonymous 2010). In the present article the status, retrospective and prospects of castor is reviewed.

Oil Extraction and Refinement

Castor oil can be extracted from the seed by following two methods *viz.*, cold pressing and solvent extraction. However, extraction of oil from castor seed can be done by combination of both mechanical pressing and solvent extraction. In mechanical pressing, the seeds are crushed and then adjusted to low moisture content by warming in a steam - jacketed vessel, thereafter the crushed seeds are loaded into hydraulic expeller and they are pressed by mechanical means to extract oil. Extracted oil is filtered and collected in a settling tank. Material removed from the oil is called as foot and can be again fed back into the stream of fresh material for further complete expelling. Material discharged from the press is called as cake which contains about 8 to 10 per cent oil. The oil from mechanical pressing has light colour and low free fatty acids (Kirk-Othmer, 1979). The mechanical pressing will only remove about 40-50 per cent of the oil present and the remaining can be recovered by solvent extraction (Ogunniyi, 2006). In the solvent extraction method, the crushed seeds are extracted with a solvent in a commercial extractor; solvents used for extraction include heptane, hexane and petroleum ethers (Ogunniyi, 2006).

Usually soon after obtaining crude oil from mechanical pressing and solvent extraction, it will be subjected to refining. The main aim of refining is to remove colloidal matter, free fatty acid, colouring matter and other undesirable constituents which make the oil more resistant to deterioration during storage. Main steps of vegetable oil refining include:

1) Removing colloidal matter by settling and filtration
2) Neutralizing the free fatty acid by sodium hydroxide,
3) Removing coloured components by bleaching agents and
4) Deodorizing by treatment with steam at low pressure and high temperature

The common method of refining used for edible oils is applicable to castor oil (Ogunniyi, 2006). Refining of castor oil can be attributed to the fact that some impurities and other components are removed during oil refining. Moreover, the pH value of the crude oil is found to be around 6 indicate that the oil is more acidic compared to refined oil (pH 6.3).

Traditional / Indigenous Method

Traditionally, castor oil extraction and processing consist of collection of castor seeds from dried capsules, open and discharging the seeds. The seeds are then cleaned, decorticated, cooked and dried prior to extraction. Cooking is done at 80^0 C under air tight condition in order to coagulate protein, which is necessary to permit efficient extraction and to free the oil for efficient pressing. After this, the material is dried at 100°C, to reduce moisture content of approximately 4 per cent (Ogunniyi, 2006). The main steps includes in traditional way of castor oil extraction is as follow.

1) *Cleaning* : Removal of unwanted materials such as stones and dirt from the dehulled seeds manually

2) *Boiling* : The decorticated seeds boiled in water to a temperature of about 80 - 95 ^{O}C for about 10 minute

3) *Drying* : The boiled seeds have to be spread on the open floor to facilitate sun drying. The drying process reduces the moisture content to about 4-7 per cent

4) *Grinding* : Sun dried seeds have to be grinded to form paste using manually operated grinding machine

5) *Mixing with water* : The paste is then mixed with water in the proportion of 1 kg of paste to 2 liters of water,

6) *Cooking* : The castor pastry is then placed on fire for heating, as the water evaporates and the product becoming sticky, oil starts gushing out and settles on the surface,

7) *Scooping of oil* : The extracted oil is then scooped to a separate container and the cake can be collected separately and

8) *Drying of oil* : The scooped oil is then dried by heating to reduce the moisture in the extracted oil approximately to 4 per cent

Physical Properties of Castor Oil

The physical properties of the castor oil bound to vary with mode of extraction; usually castor oil is a pale yellow liquid with a distinct taste and odour. As per the analytical examination, oil subjected to various important parameters indicated that, specific gravity, viscosity, density, thermal conductivity, specific heat, flash point, pour point, boiling point of castor oil showed superiority over standard synthetic lubricant (Table 1).

TABLE 1

Physical properties of castor oil

Parameters	Values
Specific gravity	0.926 - 0.963
Viscosity (centistokes)	889.3
Density (g/mL)	0.959
Thermal conductivity (W/m°C)	4.727
Specific heat (kJ/kg/K)	0.089
Flash point (°C)	145
Pour point (°C)	2.7
Melting point (°C)	–2 to –5
Refractive index	1.480

(Source : Patel *et al.,* 2016)

Chemical Properties of Castor Oil

The chemical properties of castor oil can also vary with the method of extraction. Cold pressed castor oil has low acid value, low iodine value and a slightly higher saponification value than solvent - extracted oil and it is lighter in colour (Ogunniyi, 2006) (Table 2). Further, data on fatty acid profile of castor given by Ogunniyi (2006) indicated that, apart from *ricinoleic* acid, other fatty acids present in castor oil are linoleic (4.2%), oleic (3.0%), stearic (1%), palmitic

TABLE 2

Chemical properties of castor oil

Properties	Cold pressed oil	Solvent – extracted oil	Dehydrated oil
Acid value	3	10	6
Iodine value	82–88	80–88	125–145
Saponification value	179–185	177–182	185-188

(Source : Damirchi *et al.,* 2011)

(1%), dihydroxystearic acid (0.7%), linolenic acid (0.3%) and eicosanoic acid (0.3%). The oil is characterized by high viscosity although this is unusual for a natural vegetable oil and is mainly linked to hydrogen bonding of its hydroxyl groups. It is also soluble in alcohols in any proportion but it has only limited solubility in aliphatic petroleum solvents. Although castor oil is a unique naturally - occurring polyhydroxy compound, the very limitation of the oil is that, a slight reduction of its hydroxyl value and acid value upon storage; both values may change by about 10 per cent if stored for about 90 days under normal storage condition. The reduction of these values is due to the reaction between hydroxyl and carboxyl groups in the oil molecule to form estolides (Ogunniyi, 2006).

Uses of Castor Oil

Castor oil is a multi-purpose vegetable oil with great medicinal and industrial importance; people have used it since thousands of years. The castor seeds bio - chemically contain a toxic enzyme called *ricin* which is potent and highly toxic to eukaryotic cell. However, upon heating deactivation of ricin can be achieved and which allows the oil to used safely. All part of the castor plant contain toxin but seeds contain highest concentration (Steenkamp, 2005). The details of medicinal, industrial and pharmaceutical usage of castor is given in the Table 3.

Industrial Application

Castor oil is used as raw material in numerous industries for the production of a wide variety of products. Dwivedi and Sapre (2002) utilized castor oil in production of total vegetable oil greases. Total vegetable oil greases are those which functions as both lubricant and gellant are formed from vegetable oil. Mutlu and Meier (2010) stated that castor oil is one of the most promising renewable raw materials for the chemical and polymer industries due to its manifold uses and to a series of well-established industrial protocols that yield a variety of different renewable chemicals formulations. Castor oil is majorly used in the chemical industry for the formulations of bio plastics, surfactants, polymers, plasticizers and specialty rubbers. Castor oil is known to be

TABLE 3

List of various important industrial utilities of castor

Industry	Products	Castor based products used
Agriculture	Fertilisers - Organic Fertilisers	Castor Meal
Food	Surfactants reducing Viscosity additives Flavourings Food packaging	Food grade castor Polyoxyethylated castor oil
Textile Chemicals	Textile finishing materials. Dyeing aids nylon, synthetic fibers& resins Synthetic detergents Surfactants Pigment Wetting Agents	Ethoxylated castor oil Sulfonated castor Oil / Turkey Red Oil Methyl 12-HSA
Paper	Flypapers defoamer Water proofing additive paper coatings	Methyl 12-HSA Glycerine
Plastics & Rubber	Polyamide 11 (Nylon 11) Polyamide 6 Polyurethane foam Plastic films Adhesives Synthetic resins Plasticizers Coupling agents Polyols	12-HSA Heptaldehyde Ricinoleic acid Methyl ricinoleate Sebacic acid Undecylenic acid Glycerine
Cosmetics & Perfumeries	Perfumery products Lipsticks Hair Tonics Shampoos Polishes Emulsifiers Deodorants	Castor oil Castor oil esters Undecylenic acid Castor wax Zinc ricinoleate Heptaldehyde Undecylenic acid Heptyl alcohol Ethyl heptoate Heptyl acetate
Electronics & Telecommunications	Polymers for Electr - onics & Telecommuni - cations Polyure thanes Insulation Materials	Castor oil esters Polyols

Industry	Products	Castor based product used
Pharmaceuticals	Anthelmintic drugs Antidandruff Cathartic (Substance that accelerates defecation) Emollient Emulsifiers Encapsulants Expectorant Laxatives & Purgative Additives & Excipients	Glycerine Undecylenic acid Zinc undecylenate Enanthic anhydride Calcium undecylenate, hydrogenated Castor oil
Paints, Inks & Additives	Inks Plasticizer for Coatings, Varnishes Lacquers, Paint Strippers, Adhesive Removers, Wetting & Dispersing, Additives	Polyols, glycerine Dimer acid Ricinoleic acid Castor oil Dehydrated Castor oil (DCO)
Lubricants	Lubricating grease Aircraft lubricants Jet engine lubricants Racing car lubricants Hydraulic fluids Heavy duty - automotive greases Fuel additives Corrosion inhibitors	Dimer acid Ricinoleic acid Castor oil esters Blown castor oil Heptanoic acid Hydrogenated - Castor oil Hydroxy amide - Waxes 12 Hydroxy Stearic - acid, Sebacic acid Ethoxylated - Castor oil

biodegradable and environmental friendly substances, with a wide array of applications in the biomedical, elastomers and packaging materials industries (Maisonneuve *et al*., 2013). Manufacturing of biodegradable polyesters are one of the most common applications of castor oil (Kunduru *et al*., 2015). Castor oil is also used for developing low pour point lubricant through the synthesis of acyloxy castor polyol esters (Kamalakar *et al*., 2015). Performance of castor oil as a fuel indicated that, reduction of smoke by 50 - 70 per cent at a 1 per cent oil - fuel ratio and it was on par with standard product specification (Singh, 2011). Important groups of products containing castor oil are oil-based formulations of lubricants, grease, functional fluids, process oils, oleochemicals, reactive components for paints, coatings, inks, polymers and foams, textile finishing agents, emulsifiers, stabilizers in vinyl compounds and wetting agents (Mutlu and Meier, 2010). The application of castor oil is not only limited to the above-mentioned products, but also used for making hydraulics and brake fluids and developing low-point lubricants to perform well under extreme cold weather conditions which are generally not possible with synthetic lubricants. Certain characteristics of castor oil derivatives, like high lubricated and melting point and insolubility in aliphatic petrochemical fuels and solvents make it useful as a lubricant for equipment operating under extreme conditions (Yao *et al*., 2010). Hence, castor oil is popularly termed as 'Super Lubricant'. Johnson (2007) identified a broad list of castor derivatives considered safe as cosmetic ingredients. Enormous growth of chemical, cosmetic and personal care industries encountered over the period of time increased the demand for castor oil, which is expected to drive revenue growth in global castor oil market over the forecast period. Use of renewable and biodegradable materials for production of polyurethanes is increasingly demanded by both industry and society due to energy and environmental concerns (Sharma and Kundu, 2006 and Xu *et al*., 2008).

Health Benefits

The health benefits of castor oil is known as early as egyptian civilization, in ancient Egypt, castor oil was burned as fuel in lamps, used as a natural remedy to treat ailments like eye irritation and even given to pregnant women to stimulate labour. Ricinoleic acid the major fatty acid present in castor oil has a variety of health benefits. Donwitz (1979) observed that Ricinoleic acid influences inhibition of water and electrolyte absorption in the gastro intestinal tract, stimulation of water secretion into the intestinal lumen (Ammon and Phillips, 1974) and depression of small bowel contractile activity (Ammon *et al*., 1974). Mordenti *et al*. (1982) reported that ricinoleate treatment has significant effect on decrease of plaque acid production and probably retardation of gum and tooth disease processes. Study conducted by Villeneuve *et al*. (2005) indicated that, castor oil is capable of producing conjugated linoleic acid isomers. According to Ha *et al*., 1987; Pariza and Hargraves, 1985, conjugated linoleic acid inhibits the initiation of mouse skin carcinogenesis in mouse fore stomach (Ha *et al*., 1990) and rat mammary tumorigenesis (Ip *et al*., 1991). More over, conjugated linoleic acid has been reported to be effective in preventing the catabolic effects of immune stimulation (Cook *et al*., 1993; Miller *et al*., 1994) and to change the low - density lipoprotein / high - density lipo protein cholesterol ratio in rabbits (Lee *et al*., 1994). In the traditional Indian medicine, the leaf, root and seed oil of castor plant have been used for the treatment of inflammation and liver disorders (Kirtikar and Basu, 1991), as laxative (Capasso *et al*., 1994), hypoglycemic (Dhar *et al*., 1968), hepato protective (Yanfg *et al*., 1987; Visen *et al*., 1992), diuretic (Abraham *et al*., 1986) and antibacterial (Verpoorte and Dihal, 1987). In addition, the effects of conjugated linoleic acid on human's body composition such as fat loss and lean gain are attracting increasing attention (Keim, 2003). Jombo and Enenebeaku (2008) have been reported that extract and oil from fermented castor seed are having antibacterial effects against *Klebsiella pneumoniae*, *Escherichia coli*, *Proteus vulgaris*, and *Staphylococcus aureus*. They also described those active antibacterial ingredients in castor oil should be identified for humans medication. Castor oil has been used as purgative since ancient times and it is still considered to be safe and effective laxative. Even today castor oil remains a popular natural treatment for common conditions like constipation and skin ailments and is commonly used in natural beauty products. Lam *et al*. (2004) tried to link antibodies with *ricin* A-chain which can able to target cancer cells without harming adjacent normal cells. Ilavarasan *et al*. (2006) also showed that castor oil has anti - inflammatory and free radical scavenging activity. There are many bioassays clinical studies indicated proven anti-fertility properties of castor bean in human being (Isichei *et al*., 2000; Das *et al*., 2000; Sandhyakumary *et al*., 2003). Roots and aerial parts have also been shown to be useful in the treatment of diabetes (Pullaiah and Naidu, 2003). In recent years, conjugated linoleic acid, as a dietary supplement, is produced through chemical isomerization of linoleic acid, which results in the by - production of unexpected isomers. However, recent studies have revealed that each isomer can have different effects on metabolism and cell functions and acts through different cell signalling pathways (Wahle *et al*., 2004). Shokeen *et al*. (2008) reported that root of this plant is also useful as an ingredient of different prescriptions for nervous diseases and rheumatic affections such as pleurodynia, lumbago and sciatica.

Plant Nutrient

With the gain in interest towards organic food production and consumption, the demand for enormous quantity of castor meal cake generated after extraction was increased over the years. Castor cakes serves as good source of plant nutrient (Akande *et al*., 2012). The high nitrogen content (75 g kg^{-1}), fast rate of mineralization and nematicidal effect is associated with castor meal. The mineralization of this organic material as measured by microbial evolution of carbon-di-oxide and was seven times faster than farm yard manure and 15 times faster than bagasse of sugarcane (Gupta *et al*., 2004). Castor meal used as organic fertilizer has been shown to promote the growth in crops like wheat and castor plants (Lima *et al.,* 2011). Because of the fast mineralization of nitrogen castor meal should not be added to the soil at rates higher than 45 g kg^{-1} of soil (Lima *et al.,* 2011). Again, Lima *et al.* (2011) also studied on primary and secondary plant nutrient profiling of castor cake and husk (Table 4), indicated that, significant amount of major and secondary plant

TABLE 4
Plant nutrient profile of castor cake

Nutrient	Castor meal (g kg^{-1})	Castor husks (g kg^{-1})
Nitrogen	75.4	18.6
Phosphorus	31.1	2.6
Potassium	6.6	45.0
Calcium	7.5	6.7
Magnesium	5.1	3.8

(Lima *et al.,* 2011)

nutrients were observed besides appreciable amount of oil (4 to 6 %), protein (32 %) and tracesof magnesium, zinc and copper (Gupta *et al*., 2004). Castor husks are another castor by-product that can be used as organic fertilizer. They have high K content (45 g kg^{-1}) but low N content (18.6 g kg^{-1}). Consequently, the husks need to be blended with a nitrogen rich organic material to provide a better nutrient balance for plant growth (Lima *et al*., 2011).

Crop Protection

The toxin chemical constituent *ricin* present in castor meal adversely affect the soil borne pathogens, many studies conducted in various part of the world revealed that nematode growth and survival was adversely affected by castor meals and leaf powder and leachates. Butool *et al*. (1998) opined that, castor meal anti-nematode efficiency was comparable to the nematicide *aldicarb* and *carbofuran* in the reduction of *Meloidogyne incognita* population and promotion of growth of *Hyoscyamus muticus* L. Castor meal reduced parasitic nematodes infecting pigeon pea and promoted free-living beneficial predatory nematodes (Akhtar and Mahmood, 1996). Rice plants (*Oryzasativa* L.) infested with *Meloidogyne graminicola* Golden and Birch field benefited by the addition of 5 g of castor meal kg^{-1} of soil (Prasad *et al*., 2005). Castor leaves increased the effect of castor meal against *Meloidogyne incognita* attacking lentil and okra plants (Wani, 2006). An extract of castor leaves killed 86 per cent of *Meloidogyne exigua* juveniles in coffee plants (Amaral *et al*., 2009). Tomato plants growing in a soil infected with *M. incognita* benefited from the addition of 24 kg ha^{-1} of ground castor fruits (Mashela *et al*., 2007). Castor leaf extract was more effective than carbofuran against *Meloidogyne incognita* attacking tomato plants (Radwan *et al*., 2007). Castor meal also had a synergistic effect with the nematicide carbofuran, on the reduction of root-lesion nematode (*Pratylenchus delatteri* Luc.) and on the increased growth of crossandra (*Crossandra undulaefolia* Salis.) plants (Jothi *et al*., 2004). Castor leaves and fruits added to the soil increased yield of tomato and reduced root galling and reproduction rate of *M. incognita* (Kaskavalci *et al*., 2009). Leaves were more effective against *Meloidogyne javanica* if a powder was mixed in the soil than if chopped leaves were placed in the soil surface (Lopes *et al*., 2011).

World Scenario of Castor

The castor oil contributes less than one per cent to the world vegetable oil production (Scholz and Silva, 2008 and Severino *et al.,* 2012). Globally, consumption of castor oil increased more than 50 per cent during the past three decades. European Union increased their castor oil consumption from 88 to 127 thousand tones followed by China which was about 40 to 240 thousand tones. As a result, world consumption of castor oil was elevated to 50 per cent more over the past three decades (Anonymous, 2018a). The United States has exhibited only a moderate growth in castor oil import while usage was declined in both Japan and Brazil (Severino *et al*., 2012). A slight reductions in global annual consumption of castor oil declined due to recessionary periods it could be due to decline in industrial production (Severino *et al*., 2012) (Fig. 1). But on an average, the worldwide consumption growth of castor oil is increasing at a rate of 7.32 thousand tons per year (Anonymous, 2018a).

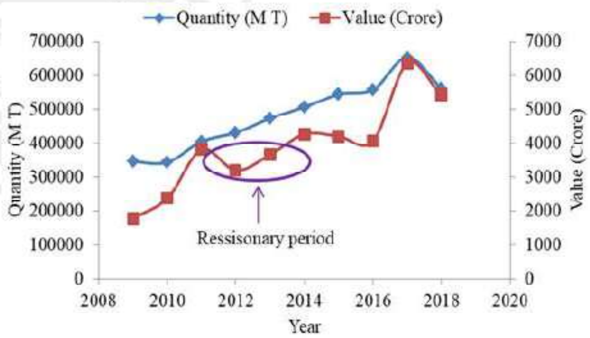

Fig. 1: Export and foreign revenue from Indian castor

Source : Food and Agriculture Organization (2018)

India, Mozambique, Brazil, China, Angola, Myanmar, Kenya, South Africa, Vietnam and Madagascar are the top ten producer of castor (Anonymous, 2018a), India contributes lion share to total cultivated area (75 %) in the world (Fig. 2) (Anonymous 2018a), apart from India Mozambique and Brazil are the two major countries which are also having 13 and 5 per cent of

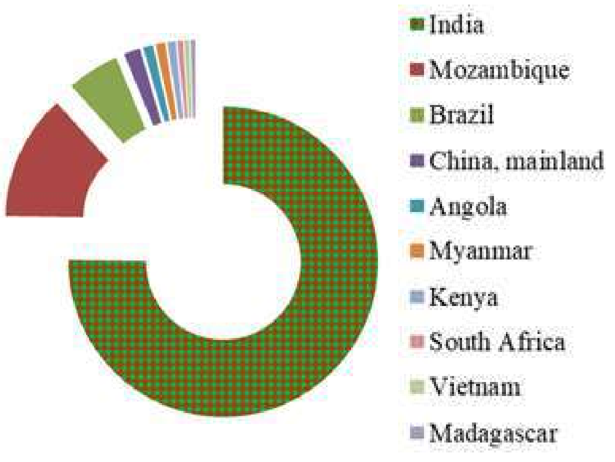

Fig. 2: India position in harvested area of castor in the world

Source : Food and Agriculture Organization (FAO). (ON1406)

global castor acreage, respectively (Anonymous 2018a).

In spite of decrement trend in area under castor, the production of castor is exhibiting a gradual increasing trend over the years (Anonymous, 2018a). Of the total global production of 19.87 million tons, India was responsible for producing 17.52 million tons during 2017-18 which accounted about 88.15 per cent of global production (Food and Agriculture Organization 2018) (Fig. 3). The significant contribution of India

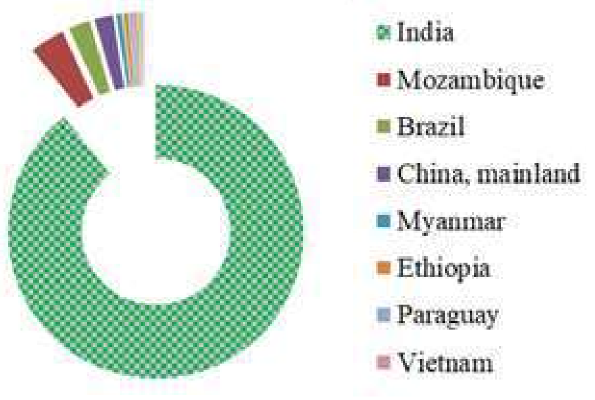

Fig. 3: India's position in production of castor in the world

Source : Food and Agriculture Organization (FAO). (ON1406)

towards the global castor production was attributed by tremendous growth in hybrid technology coupled with crop production and protection technologies (Anonymous, 2018c). However, Mozambique (4 %), Brazil (2 %), China (2 %) also contributing towards global castor production and are next to India (Anonymous, 2018a). In India, Castor Variety Improvement Programme has been initiated between 1920 and 1930 with the development of high - yielding, non-shattering, multiple branching, long duration (220-270 days) varieties with high oil content (HS-6 and HC-7). The initial breeding efforts increased 10 to 20 per cent yield and 1 to 2 per cent oil content over the local varieties.

The break through came in during late 1960s with the release of a short duration (110-150 days) variety, 'Aruna'. It was developed from the very long duration variety, HC-6 (220-280 days) through thermal neutron mutagenesis. The alteration of several morphological features of HC-6 through mutation breeding facilitated 'Aruna' variety to be more responsive to intensive management practices. Subsequently many varieties were developed and released for commercial cultivation in different states of India (Table 5) (Anonymous, 2010, 2018c and 2019).

In India, the major break through in productivity came through exploitation of heterosis. Continuous breeding efforts made under the All-India Coordinated Research Project on Castor have led to release of several high-yielding castor hybrids (Table 5). Commercial hybrid development in India has started with introduction of a pistillate line, TSP-10R, from Texas in 1965. An indigenous pistillate line, VP-1 derived from TSP-10R and several derivatives of VP-1 have been used as a pistillate line in the released commercial hybrids in India. The first castor hybrid, GCH-3, yielded 124 per cent higher over the varieties under cultivation; however, the seed shattering nature of this hybrid forced pre-mature harvesting. Hence, it was replaced later by a non-shattering hybrid, GAUCH-1. However this hybrid was highly susceptible to *Fusarium* wilt and *Macrophomina* root rot. This has been later replaced by the hybrid, GC-2, which was tolerant to root rot to some extent but not to wilt. With the development of GC-2, castor cultivation has spread rapidly, owing to high economic returns. Mono cropping of castor has resulted into endemic development of *Fusarium* wilt in castor growing areas of Gujarat. This has necessitated the

TABLE 5

List of castor hybrids released and recommended for different regions

Hybrid	Year of release	Duration	Oil content (%)	Average yield (kg/ha)		Recommended Region
				Rainfed	Irrigated	
GCH-3	1976	140-150	49	-	1540	Gujarat
GAUCH-1	1976		49	-	1520	Gujarat (Irrigated), Southern India (Rainfed)
GCH-2	1986	200-210	48	-	1700	Irrigated areas of Gujarat
GCH-4	1988	150-180	50	1200	2200	Dry as well as irrigated conditions: under sandy loam, red and black soils of Karnataka
GCH-5	1997	180-240	51	1800	2000	Irrigated areas of Rajasthan and Gujarat
DCH-32	1998	85-95	48	1700	2500	Rainfed areas of hot semi-arid Deccan plateau (Andra Pradesh, Tamil Nadu and Karnataka) and Irrigated areas of Maharashtra.
GCH-6	1999	210	48	1400	2300	Irrigated castor growing areas of Gujarat, Maharashtra and Rajasthan
DCH-177	2000	90-100	49	1800	2500	Rainfed areas of hot semi-arid Deccan plateau (Andra Pradesh, Tamil Nadu and Karnataka) and irrigated areas of Maharashtra)
RHC-1	2000		49	900-1200	2500-3000	Rainfed areas of Andra Pradesh, Tamil Nadu, Orissa, irrigated areas of Rajasthan and Maharashtra.
PCH-1	2001	150		1500	2000	Rainfed areas of A.P.
DCH-519	2006	140-150	49	1500	2200	Both rainfed and irrigated castor growing areas of the country
GCH-7	2006	140-150	49		2450	Irrigated areas of Gujarat
YRCH-1	2009	150-160	49	1861		Tamil Nadu
GCH-8	2017		48	1895	3588	All castor growing areas of the country
YRCH-2	2017		48	2089		Tamil Nadu
GCH-9	2018	110-120	47-48	-	3820	Irrigated areas of Gujarat
VI-9	1973	150-210	47	1200	1500	Rainfed areas of Gujarat
Bhagya	1978	100-150	51	1000	-	Andhra Pradesh
Sowbhagya	1978	100-110	50	1200	-	Andhra Pradesh

Hybrid	Year of release	Duration	Oil content (%)	Average yield (kg/ha)		Recommended Region
				Rainfed	Irrigated	
CH-1	1978	120-180	49	1800	-	Rainfed areas of Haryana and Punjab
RC-8	1982	180-240	48	1180	-	Rainfed areas of Karnataka
TMV-5	1985	120-150	48	950	-	Rainfed areas of Tamil Nadu
GC-2	1994	150-180		-	2100	Irrigated castor growing areas of Gujarat
AKC-1	1995	120-150	48	1200	-	Rainfed areas of Maharashtra
Jyoti (DCS-9)	1995	90-150	49	1000	-	Rainfed areas of A.P., Karnataka, Tamil Nadu
Kranti (PCS 4)	1996	90-150	49	1000	-	Rainfed areas of Andhra Pradesh
TMV-6	1997	120-180	52	930	-	Rainfed areas of Tamil Nadu
Harita (PCS-124)	2002	90-180	49	1400-1600	-	Light soils of southern Telangana, Rayalaseema and Prakasam District.
Kiran (PCS-136)	2002	110-180	51	1200-1500	-	Rainfed areas and late sown *kharif* conditions in Andhra Pradesh with one or two irrigations
Jwala (48-1)	2007	130-220	50	1000	1800	All castor growing areas of the country
GC-3	2009	100-210	49	-	2340	Irrigated castor growing areas of Gujarat
DCS-107	2011	120-130	46	1500	1700	All castor growing areas of the country
Perennial castor variety						
CO-1	1977	1-10 years	49	2 kg/tree/year	-	Sub marginal lands of Tamil Nadu
Tarai-3(T-3)	1978	235	55	1100-1400	-	Alluvial soils of Uttar Pradesh
Tarai-4(T-4)	1978	240	52	1100-1400	-	Bundelkhand of Uttar Pradesh
YTP-1	2018	115-120	48	1456(3kg/plant/annum)	-	Rainfed areas of Tamil Nadu

development of *Fusarium*-wilt resistant hybrids in India. The most popular wilt-resistant high-productive hybrid, GCH-4, has replaced GC2. GCH-4 has ruled castor cultivation until recently. Farmers have realized 48-158 per cent increased yield from GCH-4 under both rainfed and irrigated conditions. The GCH-5, a wilt-resistant hybrid, released in 1995 gave 13 per cent more yield than GCH-4. Besides a series of hybrids, GCH-6, GCH-7, DCH-30, DCH-177, DCH-519, YRCH-1 and PCH-111 have been released under All-India Coordinated Project on Castor. Most of these hybrids have capacity to yield around 1500-1600 kg/ha under rainfed conditions and more than 2000 kg/ha under irrigated conditions. All these hybrids are of medium duration (5-6 months) and resistant to *Fusarium* wilt possessing 48-51 per cent oil content. These hybrids were highly responsive to irrigation and fertilizer. Currently, GCH-7 has taken a dominant place among all Indian castor hybrids because of its high productivity and wilt resistance. It has increased national average of per hectare yield of castor. It is having an yield potential of around 1500-1800 kg per hectare under rainfed and 3000-3200 kg per hectare under irrigated conditions.

Among the various countries involved in castor cultivation, Syrian Arab Republic ranks first in the productivity despite of negligible area under cultivation (Anonymous, 2018a). However, among the major castor producing countries India is having relatively higher yield per unit area harvested (1786 kg per hectare) and was closely followed by China (1739 kg per hectare), Iran (1681 kg per hectare) and Ecuador (1500 kg per hectare) (Fig. 4).

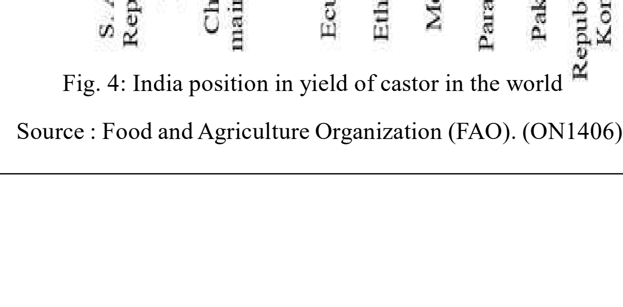

Fig. 4: India position in yield of castor in the world

Source : Food and Agriculture Organization (FAO). (ON1406)

In India, Gujarat, Rajasthan and Haryana are the three states which contribute more than 90 per cent to total production an account of significant excellence in productivity (Table 6). The excellence in productivity of castor in these states could be due to subtropical climatic conditions and labour-intensive cultivation under assured irrigation (Anonymous, 2018c). According to data published by the Government of Gujarat, castor seed production in India increased by almost 10 per cent to reach 1.5 million tonnes for the year 2016-17, which clearly signifies the fact that, the availability of castor seeds is in copious, resulting in large production of castor oil, which is anticipated to boost the overall growth of the castor oil market globally (Solvent Extractors' Assoc. of India 2018).

TABLE 6

Area, production and productivity of castor in various states of India

States	Area (In ' 000 Hectare)	Production (In 000 tones)	Productivity (In Kg/ha)
Andhra Pradesh	33.00	16.00	485
Arunachal Pradesh	0.17	0.09	540
Assam	0.74	0.35	465
Bihar	0.08	0.07	961
Gujarat	541	1121	2072
Haryana	1.3	1.69	1300
Jharkhand	0.16	0.07	422
Karnataka	9	5	556
Madhya Pradesh	14	6	429
Maharashtra	6.9	2.1	304
Meghalaya	0.07	0.01	100
Nagaland	0.34	0.23	676
Odessa	8.91	5.62	631
Rajasthan	142.47	190.68	1338
Tamil Nadu	4.71	1.47	312
Telanagana	45	26	578
West Bengal	0.06	0.04	629
India	**807.92**	**1376.42**	**1704**

Source: Anonymous 2018b (Directorate of Economics and Statistics, Govt. of India. 2018)

Yield Gap

Yield gap is the difference between two levels of yield. Yield gap - I is the gap between potential yield of a variety and the yield of improved variety at the research station. Similarly, yield gap - II is the difference between the yield of improved variety at the research station and at farmers' field. When this is being the situation, data acquired and compiled from the various sources indicated that, in spite of significant superiority in compound growth rate of castor among the oilseeds there is a vast gap in the yield. The demonstrations conducted just by inclusion of improved cultivar the realizable gap observed was 70 per cent in castor (Table 7). Further, it is known that, yield disparity among the castor growing states in India is very much higher and usually yield levels of Southern states (Karnataka, Tamil Nadu, Telangana, Andra Pradesh and Orissa) are much lower than Northern states (Gujarat, Rajasthan and Haryana) (Fig. 6). Hence, there is a great scope for castor in India to exploit yield reservoirs through hybrid technology and agronomic interventions (Fig. 5).

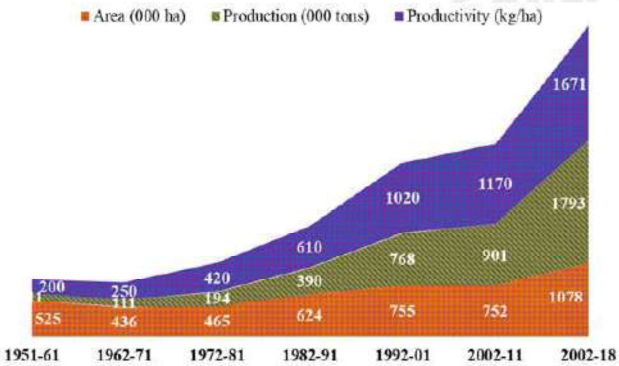

Fig 5: Decadal growth trends of castor in India

Source: Anonymous 2018b (Directorate of Economics and Statistics, Govt. of India. 2018)

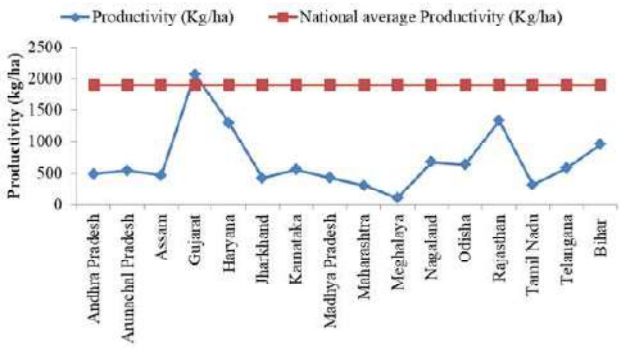

Fig. 6 : Average productivity of castor as compared to national average productivity

Source: Anonymous 2018b (Directorate of Economics and Statistics, Govt. of India. 2018)

Challenges and Research Priorities

Initially in castor no intensive breeding work happened as in food or other commercial oilseed crops. The initial constraints in castor were just confined to low yield, long duration, indeterminate growth habit, shattering,

TABLE 7

Average productivity of castor in front line demonstrations and exploitable yield reservoirs of castor in India

Crop	No. Demonstration conducted	Average yield of front line demonstrations (kg/ha)	Average yield (kg/ha)	National average yield	Yield gap-II (%)
Groundnut	105	22022	1294	1900	70
Soybean	718	1734	1206	1900	44
Mustard	185	1591	1161	1900	37
Sunflower	140	1356	729	1900	86
Sesame	160	784	386	1900	103
Safflower	210	1315	511	1900	157
Niger	48	357	306	1900	81
Castor	217	2704	1592	1900	70
Linseed	323	848	412	1900	106

Source: Compiled from various sources

susceptibility to frost, drought and large number of insects and pests. Globally, 8699 castor germpasm accessions were maintained of which 4307 accessions are preserved in India (Anjani, 2014). The available germplasms in castor represent a rich repository of genetic variation, which formed the basis for castor breeding in early days. The early taxonomists and botanists from USSR and USA initiated their work towards the development of varieties by exploiting natural variation between 1773 and 1976 (Anjani, 2014). However, basic objective of those days castor breeding had concentrated on seed yield. Development of genotype with short duration, lower number of nodes on main stem, productive long primary and secondary racemes, higher number of capsules on a raceme, high seed weight, high oil content, resistance to major diseases are the order of the day.

Castor being a crop of tropics, perform well under diverse edaphic and climatic conditions. Based on its unique physical, chemical and medicinal properties it has gained the global importance. Under the scenario of climate change, castor could be one such option to answer the risks of rainfed ecosystem. India being the major producer of castor through the country is benefiting with countable foreign revenue, still there is a scope to enhance productivity by bridging gaps in yield under rainfed situation through technological advancement and their outreach.

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(*Received :* November, 2019 *Accepted :* February, 2020)