J Hum Ecol, 38(3): 213-222 (2012)
PRINT: ISSN 0970-9274 ONLINE: ISSN 2456-6608 DOI: 10.31901/24566608.2012/38.03.06

A Historical Policy Review of Success of Castor Revolution in Gujarat, India

D. D. Tewari

School of Accounting, Economics and Finance, University of KwaZulu-Natal, South Africa

KEYWORDS Castor Hybrids. Commercialization. Germplasm. Breeding. Adoption

ABSTRACT The study explains with respect to various policy parameters which enabled castor crop to become an economic success in Gujarat in 1980s and thereafter. The policy overview suggests that it was a combination of a good breeding program, a good extension model, coupled with access to well-developed national and international markets. All these led to a rapid commercialization success of the castor crop. The study confirms that a simultaneous development of all three programs—breeding, extension, and market development—is the key to the success of any technological change.

1. INTRODUCTION

Castor is a non-edible oilseed crop; the output of this crop is in the form of beans which when crushed produces oil and cake. Castor oil has a large international market[1]. Castor oil is used in more than 700 industrial products and its demand is increasing by 3-5 percent per annum (Anjani 2011). India is the largest exporter of castor oil in the world market. Historically Brazil occupied the place of the largest producer and exporter of castor oil in the world but its production and relative share in the international market has shrunk significantly in the past few decades. As opposed to this, India has gained a major place in the marketplace and its production and export of castor oil have risen significantly since mid-or late 1970s (Tewari and Rao 1991; http://www.crnindia.com/commodity/castor.html). Castor is grown in some 30 countries. India, China, and Brazil are the major producers. They respectively contribute 65, 23, and 7 percent of the world total production. The world production of castor seeds hovers around at an average of 1.25 million tonnes and castor oil of about 0.55 million tonnes per annum (http://www.crnindia.com/commodity/castor.html).

In 1950's, castor was a crop of low value and was primarily grown in dry areas of Andhra Pradesh, a state in southern India. But over the years, the center of castor production has shifted to Gujarat, a state in western India. Interestingly enough, most of the increase in castor production has come from Gujarat where this crop has become a major cash crop in the farmers' portfolio. Gujarat accounted for about 70 percent of country's total castor production with only one-third of the total castor acreage in the country during 1990s (Tewari and Rao 1991: 28). Gujarat alone contributes to 86 percent of the total castor seed production in India today (www.crnindia.com/commodity/castor.html).Also, castor yields in Gujarat farms have remained the highest in the world since 1970s, more than twice of the world average (Tewari and Rao 1991: 94; http://www.crnindia.com/commodity/castor.html). The current yield in Gujarat is about 1830 kg/ha. The yield has registered a three- fold increase since 1970, although the general productivity levels in other parts of the country stagnated around 480 kg/ha (http://www. ikiasam.com/links/ap_castor History. shtml). Therefore, it is not an exaggeration to call Gujarat the castor bowl of the India.

The increased castor production has led to increased exports of castor oil, making India a major exporter of castor oil. It has come a long way. For example, average annual production of castor during the 1961-65 period was only 105 thousand tonnes, rising to the annual average of 198 thousand tonnes during the 1976-80 period, 348 thousand tonnes during 1981-85, and further increasing to 500 thousand tonnes in 1990. Although there were three bad years from 1986 to 1988 owing to drought in western India, the production further climbed up to 625 thousand tonnes in 1994 and 800 thousand tonnes in 1996. The production touched a high of 900 thousand tonnes in 2007/8 and is expected to reach 1.1 million tonnes in 2008/9, and to about 1.2 million tonnes in 2010/11 (Anonymous 2009).

There is something unique about the spectacular success of castor crop in Gujarat. After the successful indigenous breeding programs for wheat and rice during the late 1960s and 1970s in the country, castor was the third crop in the country which had a very effective internal breeding program and this finally catapulted the country into the world castor market as a major player. It is to note that despite large investments made in the breeding programs of other crops like sunflower, groundnut, maize, sorghum, pearl millet, pigeon pea, these crops never met with an overall spectacular success as did castor. Unlike wheat revolution in the 1960s, which succeeded on account of exotic Mexican seeds, the success of castor crop can be primarily attributed to the spread of indigenously developed castor hybrids. In addition to hybrid seeds, there are a number of other factors which contributed to the success of the crop. An understanding of these factors and policies is essential for future policy-making and also for transplanting this experience elsewhere.

Objectives

The objectives of this study are to discuss the history of events and policies that contributed to successful commercialization of the castor crop which put India on the world map and also to show how the lessons from this historical experiments can be used effectively elsewhere. More specific objectives of the study are:

- to discuss a policy framework under which castor crop catapulted into a success story;
- to analyze the three pillars of success which included castor breeding program, rapid adoption of the crop through a good extension strategy, and finally rapid market development and commercialization of crop in the country; and
- to derive major policy lessons with specific respect to crop development in India.

An overview of successful policies and related events is explained with the help a schematic model in section 3. The three pillars of this model are then discussed consecutively in the next three subsections. The conclusions and major policy lessons are discussed at the end in section 4.

3. THE POLICY OVERVIEW OF HISTORICAL SUCCESS OF CASTOR CROP

The success story of castor hybrids in Gujarat can be explained with the help of a

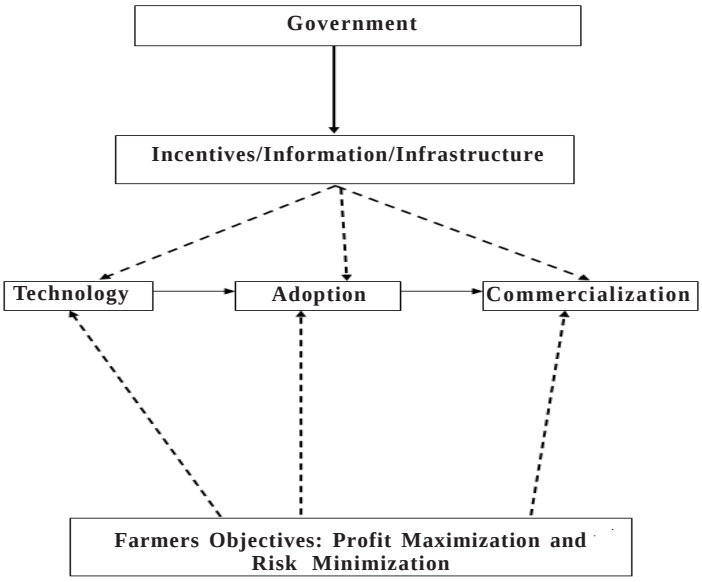

Fig. 1. A schematic model of castor revolution success

conceptual policy model (Fig. 1). The model divides the entire development into three phases: (1) a successful castor hybrid breeding program in the country and in particular in Gujarat; (2) the successful adoption and retention of the crop by farmers in the Gujarat and diffusion over a very short span of time; (3) finally, existence of well-developed infrastructure and incentive structures which enhanced the quick commercialization of the crop.

The basic tenor of the model is that an overall success of a crop hybrid/variety, or an agri-biotech innovation in more general sense, requires sequential successes in all three phases, that is, breeding, adoption, and commercialization. That is, the innovation in question must pass some critical success criteria for all three stages. For example, successful breeding cum adoption of a high yielding variety (HYV) or hybrid may not lead to an overall success if there was not sufficient infrastructure for commercialization of the product or innovation in question. This is hence an integrative concept of success which requires certain conditions to be fulfilled at all stages of development of the HYV/hybrid/crop. The two important agents in this process are producers and government led institutions. The objective of producers or farmers is the profit maximization and risk minimization.

The government led institutions including the bureaucracy are to gear this system so as to meet producers' objective in particular and society's objective of maximizing social well-being at large, by providing a right structure of incentives and a system of information flow.

The phase one basically involves development of new variety or hybrid (genetic material); and the production of this new variety or hybrid basically depends upon three major inputs: (1) a pool of scientists including breeders, (2) scientific instruments, (3) germplasm stock. The caliber of scientific pool is the key here as it determines how effectively other two inputs—scientific instruments and germplasm material—would be used for producing new hybrid or variety; and , at the same time the scientific caliber determines the rate of growth in innovation-making. But, this does not mean that creative ingenuity of scientists may not be constrained by the availability of germplasm stock in the nature and by the investment available to purchase new scientific instruments.

In phase two, the hybrid or HYV is passed on to the targeted producers and becomes a study object for social scientists. Here, the innovation in question passes through processes of adoption and diffusion. Adoption is a mental process that goes on in an individual producer's mind from the time he/she knows about the HYV/hybrid until he/she adopts it; more specifically the process of adoption is divided into the following sub-stages such as awareness, interest, evaluation, trial, and finally adoption (Rogers 1962; Rogers and Schoemaker 1971). Having adopted the HYV/hybrid, individual producers may continue or discontinue to use the innovation depending upon his/her satisfaction and expected level of performance of the HYV/hybrid. This experience is then passed on to those who have chosen to be non-adopters yet so far. The interaction between adopters and non-adopters continues to take place; this induces some non-adopters to adopt the innovation in question. The process goes on until all the targeted producers have adopted the HYV/hybrid—this is called diffusion. The diffusion period is measured from the date when first producer in an area or social system is aware of it until it has reached the every targeted producer in the system. Note that the diffusion is basically a social interaction process while adoption is a mental or cognitive process; yet both are roughly related. It is said that innovations which have shorter adoption period are likely to have a shorter diffusion period too.

The phase three involves the commercialization of the innovated product, that is, searching or developing markets for it and its derivatives. Here, it is important to mention that the time gap between phase two and three is a crucial variable in determining the success of innovation in question. Generally, it takes a lot of time to create or produce a variety or HYV/hybrid. However, having produced and delivered to targeted producers for adoption, the need for an already existent markets or verifying the potential ones for the product in question is an urgent necessity for successful commercialization. In point of fact, the second and third phases of the development should occur simultaneously or there must pre-exist required infrastructure for verifying the commercialization potential so that targeted producers may be able to realize the expected profit from the innovation under adoption. There can be several aspects or angles with

which commercialization issue can be examined; moreover, these issues would vary with the type of innovation or product in question. The three pillars of the success in the context of castor crop are thus discussed below.

3.1 The First Pillar of Success: A Successful Castor Breeding Program

The improvement in castor crop in the world was first started in the US through selection in early 1900 AD and work on exploiting hybrid was taken up as early as 1946. Indian castor breeding program started sometimes during 1920s and 30s at Tindivanam (Tamil Nadu), Rajendranagar (Andhra Pradesh), Hebbal and Raichur (Karnataka), Nagpur and Jalgaon (Maharashtra), Nadiad and Junagadh (Gujarat), Jallandhar (Punjab), Kanpur (Uttar Pradesh). Breeders at that time focussed on improving yield, branching habit, and non-shattering characteristics. However, during the 1950s, increasing oil content was also added to the breeder's objectives. The major breeding method then used was selection through which breeders could increase yield by 10-20 percent and oil content by 1-2 percent over the local varieties.

During the 1960s, India experienced green revolution through high yielding varieties of wheat and rice brought from CYMMIT in Mexico and IRRI in Philippines, respectively. The success of these high yielding varieties impelled Indian agricultural policy planners to augment the indigenous breeding potential with a hope to have successful experiments in other crops including castor.

The breeding program at Sardar Krushinagar Dantiwala University (SDAU) has been specially successful in producing hybrids suitable for agroclimatic conditions in Gujarat. The systematic castor breeding program was started in Gujarat in 1962. A number of cultures were obtained from USA from which some 100 percent pistillate lines TSP-10-R from Texas gave way to develop hybrids (Classen and Hoffman 1950). The first hybrid GCH-3 (TSP-10R x JI-15) was found to give 88 percent more yield than local varieties. It was released as first castor hybrid in the state for general cultivation in 1968 (SardarKrushinagar Dantiwada Agricultural University or Gujarat Agricultural University (SDAU no date). Later an indigenous pistillate line, VP-1, was developed (at Vijapur centre in Mehsana District, Gujarat) and from which a combination VP-1 and XVI-9 or GAUCH-1 was developed; this gave 16 percent more yield than GCH-3. The GAUCH-1 was released for commercial cultivation in 1973 and became very popular on account of its high yield and mild resistance to jassids and whiteflies. But, overtime it was found to be very susceptible to root-rot and wilt diseases.

Other hybrid GCH-2 (VP-1 x J1-35), which gave 13 percent higher yield over GAUCH-1 and showed relative tolerance to root-rot diseases, was commercially released to supplement GAUCH-1 in 1984. Very high yields of these hybrids and their short maturity periods made castor very remunerative crop, but also disturbed the usual rotation in the farmer's land. As a result, incidence of wilt disease increased and it became limiting factor in increasing castor production[2]. To offset this disadvantage of GCH-2, a superior hybrid GCH-4, was released in 1987; this had marginal advantage in terms of yield over GAUCH-1 and GCH-2 but had major advantage in being wilt resistant[3]. The GC-2 was released in 1994 and was jassids and wilt tolerant and matured early. It gave 15 percent more yield over the previous hybrids. The GCH-5, a wilt resistant hybrid, was released in 1995 and gave 13 percent more yield than GCH-4. Since then GCH-6 and GCH -7 have been found; these are wilt and drought resistant and a large proportion of total castor acreage has now come under these new hybrids in Gujarat.

The new varieties, like Aruna, and castor hybrids such as GCH-3, GCH-4, or GCH-5 etc., were far superior to those previously developed strains in respects of duration and yield. The old improved strains took about eight months long period and gave only 10-15 percent increased yield over the local varieties (Tewari 1995). In contrast, the hybrids took half the time taken by old strains to mature. It made feasible to take two crops of castor in a row. At the same time, these hybrids were responsive to irrigation and fertilizers and yielded more than twice of the old strains. For example, on an average, yields were as high as 1000-1200 kgs/hectare under rainfed conditions and as high as 2500-3000 kgs./hectare under irrigated conditions. India thus made significant progress in developing of hybrids (Hegde et al. 2003).

The first important factor for successful castor breeding was the pivotal role played by the SDAU. The success of castor breeding at SDAU can be attributed to two critical factors: (1) The SDAU centre had wide spectrum of segregating material which was necessary for developing new pistillate lines. (2) The centre had the technological knowhow such as mutation and other techniques to create genetic variability. The super-ordinary traits of these pistillate line can be used in desired direction by crossing with suitable male parents (Gujarat Agricultural University 1991). The center developed a versatile pistillate line of castor, VP-1, which is a derivative of (TSP-10-R x J-1 F2) x (JP-5 x 26006) F2. This line was used as a female in most of the cultivated hybrids in India. Since then a number of other pistillate lines have been found. The new pistillate lines have been very useful in developing disease resistant hybrids. Thus efforts to continuously refine and develop new breeding materials have continued. The success in breeding for castor yield stability was limited by a low genetic variability for productivity traits and sources of resistance to disease and pests (Weis 2000; Hegde et al. 2003). Therefore, breeders had to resort to alternative approaches like mutations, intergeneric hybridization, and use of biotechnological tools for creation of genetic variability and incorporation of desired traits (Sujatha 1996; Lavanya et al. 2003; Sujatha et al. 2008). The mutation technique was used to induce productive semi-dwarfs with higher yield potential and earlier maturity, loss of day-length sensitivity and identification of variants of sex expression (Kulkarni and Ankineedu 1966; Ankineedu et al. 1968; Lavanya et al. 2003). As a result, the castor hybrids yielded 7-8 times of the local or traditionally grown castor seeds unlike improved varieties of other crops (Tewari 1995). This may alone explain that the innovation of the SDAU breeders was far superior to others.

The technique of ionizing radiations did wonders to the castor breeding program; dwarf varieties, maturing within 120 days as opposed to traditional ones which matured within 250-270 days, with high oil content, and responsive to fertilizers and irrigation were developed. The major improvement came through exploitation of hybrid vigor or heterosis; several attempts went into it (Pathak and Dikshit 1961; Sindgi and Ansari 1969; Akineedu and Kulkarni 1965). The most successful exploitation was then made by Gopani et al. (1969) whose F_1 yielded 124 percent over cultivated variety. This hybrid was then commercially exploited in Gujarat. Since then continuous breeding efforts were made in particular at Sardar Krushinagar Dantiwada University (SDAU) in Gujarat and in Department of Oilseed Research (DOR) at Hyderabad under the all-India coordinated project on castor.

The second important factor which led to the breeding success was that there existed an information feedback mechanism from farmers to breeders. The performance results of hybrids on farmers fields were passed on to breeders who then worked upon in overcoming the shortcomings. For example, when GCH-2 became wilt-susceptible on farmers' fields, the breeders at SDAU developed a wilt resistant GCH-4 hybrid. Similar efforts were taken up by the breeders at the SDAU to develop hybrids that are resistant or tolerant to root-rot under rainfed conditions or to drought and salinity conditions (SDAU, no date). This information feedback mechanism kept breeders aware of what farmers wanted; this very fact helped in speedy adoption of new hybrids which were developed bearing farmers' interests in mind. The breeding program was thus directly linked to the farmers' fields.

The third and the most important factor for breeding success was the stock of human capital, in particular crop breeders, agronomist, entomologists, and other agricultural experts in the country. This was made possible by establishing some more than 20 agricultural universities in India and Government of India made a heavy investment in the public research funding (Evenson et al. 1999).

3.2 The Second Pillar of Success: Rapid Adoption of the Crop

Until the third Five Year Plan (FYP) in India, very little emphasis was laid on castor, and whatever efforts were made were primarily aimed at increasing castor acreage with little emphasis on improving yield. The package approach towards increasing production was introduced in the terminal year (1965-66) of the third FYP. This approach aimed at using a package of inputs together with improved seeds, irrigation, fertilizers, plant protection measures[4]. However, expected pay-offs were not high in the absence of hybrids/mutants. Even the producers response

toward adopting these old strains was not encouraging. For example, some 174 thousand hectares were sown with old improved strains of castor—about one-third of the total castor acreage in the country—but production results were disgusting and yield levels were extremely low (Tewari 1995).

It is believed that success in adopting new strains was primarily due to the government push and perhaps producers did so to take advantage of input subsidies given under the package program. Moreover, the adoption acreage figures collected thorough government machinery were perhaps biased upward and their reliability was considered to be low.

Adoption is a well-researched area. Based upon the past studies, Rogers have propounded a middle range theory of adoption (Rogers 1962; Rogers and Schoemaker 1971). The theory describes that adoption rate is dependent upon the following set of variables: (1) perceived attributes of innovation which include relative advantage, compatibility, complexity, triability, observability; (2) types of innovation decisions which could be optional, collective, and authoritative; (3) communication channels such as mass media or interpersonal; (4) nature of social system; and (5) change agency's promotional efforts. Several studies have further strengthened the Roger's model by empirical testing. For example, the Subcommittee of Rural Sociological Society of USA (1952) found that in the US farm ownership, education, income, size of farm, and social participation are positively correlated with the readiness to adopt new practice. Some researchers have found that if a farmer was efficient, had initiative and was progressive, he/she was likely to adopt improved farm production (Holfer and Strangland 1958). Mass media exposure is also found to be significantly correlated with readiness to adopt new practices (Rogers 1965: 66). The literacy, newspaper exposure, opinion leadership, and use of technology have been found positively related to initial levels of technical knowledge. Farmers in Eastern States of Nigeria had a high degree of knowledge of farm innovation but low adoption rates (Obiuaku and Hursch 1974). Other subsidiary activities such as access to roads, water supply, health services are as necessary as seed, fertilizers, or technical know-how to increase adoption rates (Obiuaku 1979). An integrated approach to agricultural development helps in rapid adoption of innovations (Obiuaku 1979). Other factors such as resource availability can also affect adoption rate; for example, the decline in mortality in Taiwan contributed to the increase in the labor-land ratio, which finally led to the adoption of new labor-using and output-increasing rice variety (Whitney and Johnson 1979).

Castor hybrids were introduced sometimes in 1972. Almost all farmers switched to castor hybrids within a period of 4-5 years. Some 98 percent of total castor acreage in two major castor growing districts—Mehsana and Banaskantha—came under castor hybrids within five years or by 1978 (Tewari 1995) . As a result, the average castor yield in Gujarat, which was once below world and Brazilian levels, increased continuously and surpassed both of them (Tewari 1995). The average castor yield in Gujarat stands now (at present in 2011/12) more than 2000 kg/ha. There are three major reasons why the adoption and diffusion of castor hybrids in Gujarat was so quick.

Firstly, castor hybrids, with high yielding potential and remunerative castor prices in the market, became economically competitive crop to farmers. A comparison of net returns across six crops, viz., *jowar, bajra*, maize, wheat, groundnut, and castor, revealed that castor is more economical than others. For example average net returns per hectare was Rs.3816 for castor; Rs.1117 for wheat, and for the rest of them returns were negative (All figures in 1994/95 prices, based on author's calculation in Tewari (1995). The buoyant world castor prices have kept this competitiveness to date.

Secondly, besides being economically attractive, various other non-economic advantages turned the planting decisions of farmers in favour of castor crop. These advantages included: it generated cash income to farmers which helped them withstand liquidity problems; it required less supervision and management time too; it could grow in less fertile soils in which other crops could not do well[5]. It was also a discomfort-saving and less-risky crop which perfectly matched the objectives of absentee landlordism (Tewari 1995).

Thirdly, the already built-in infrastructure of marketing and retailing hybrid seeds by various private seed companies such as Nav Bharat Seeds and other and public seed companies such as Gujarat Agro Industries facilitated the process of adoption and diffusion without any hin-

drance by providing hybrid seeds to farmers on time and at the reasonable prices (Tewari 1995). The well-organized and reliable seed multiplication system built up by these firms in which quality was accorded utmost consideration, won the farmer's confidence. At the same time, sufficient quantities of nucleus and breeder seed production of released varieties/hybrids was taken up and ensured a continuous uninterrupted supply of seeds to the farmers.

3.3 The Third Pillar of Success: Rapid Commercialization of the Crop

The third phase calls for commercialization which means basically finding remunerative markets and building up required infrastructure to promote business and trade. In fact, phases 2 and 3 should occur simultaneously in back-and-forth manner. And, there must pre-exist all necessary elements that are required for marketing and trade of the new crop. Interestingly enough, there existed a well-developed marketing and trade framework prior to the introduction of castor hybrids in Gujarat by Jayant Agro company. The company was launched in 1950s by a Gujarati family who were familiar with local markets and people. It had its network for collection of castor seed throughout Gujarat where castor crop was in predominance. The company procured castor seeds from farmers, transported the produce to Mumbai, where seeds were crushed and castor oil was further refined for the resale in the export market.

In 1970s, when hybrids were introduced, Jayant Agro felt the need for promoting local milling of castor seeds and processing of castor oil so that cost economies could be obtained in transportation. They decided to set up a processing plant in Baroda. Also, instead of buying seeds directly from farmers they started buying castor oil from millers for further refinement. As a result, a large number of castor seed millers sprang in various districts in Gujarat; a large proportion (about 40 to 50 percent of the total) of that being in the industrial city of Ahmedabad.

Since international castor oil prices remained buoyant, this helped the trade to flourish uninterruptedly. If there was any problem, it was basically related to production planning and stabilizing it due to varying monsoon from year to year. Drought posed a severe strain in meeting the export demand for castor oil. During the drought years of 1986 to 1989, exports slumped primarily due to reduced production, but not due to slackness of demand.

Since then various firms have entered into the export of castor oil business. Prominent among them is the N.K. Industries Limited (NKIL). The NKIL embarked upon a huge expansion and diversification program, envisaging an investment of Rs.200 million in 1990s in the Mehsana district—the castor growing heartland of Gujarat. It planned to double the expelling and refining capacities of the business. The most interesting feature of NKIL was its price support to the castor growers.

It is important to emphasize here that the process of commercialization brings finally remunerative prices to producers and leads to the development of infrastructures for further promotion of business in question. High castor prices were well-received by Gujarati farmers. This led to spurt in castor acreage in Gujarat since 1970s. The castor acreage response to prices in Gujarat is estimated to be very high; the price elasticity to acreage was 2.28 (Tewari and Rao 1991: 49-52).

The other positive points that Gujarat had were: (1) a well-developed network of 300 assembly centres for agricultural produce in the state, (2) well-developed transportation system linking primary to secondary markets, (3) a well-developed institutional finance. The infrastructures were hence quite conducive to the promotion of business. Presumably due to above, the market imperfections, particularly for commercial crop like castor, were hardly discernible in Gujarat.

Nearness of Mumbai to Gujarat further contributed to the commercialization process in very many ways. First, futures trading in castor seed developed in Mumbai around 1900 A.D. which continues till today provided much needed hedging facilities to the traders in the market. This may have had some stabilization effect on castor prices, the fact which ultimately helped the castor business to grow. The availability of hedging facilities through future trade proved quite helpful in the first half of the 20th century to castor seed business and in the second half, that is, after 1950s, to the castor oil business. Second, the futures trade also helped to meet export commitments more smoothly. Traders were benefited to conclude maximum export busi-

ness and processors were benefited from the facility of trading in castor oil. Third, Mumbai, being business capital of India, became a source of finance to Gujarat. Big companies came to Gujarat to explore the market; Jayant Agro company was one of them. The company started the innovative approach of collection of castor seeds from door-step of the farmers at predetermined prices and transported the same to Mumbai for processing and exports.

The government of India also took suitable steps to promote export of castor oil by providing cash compensatory support, duty draw back incentives, refund of excise duty and income-tax, etc (Tewari and Rao 1991). Yet, many exporters felt that full potential of castor oil export was not utilized and hence demanded exports under "Open General Licence" (OGL).

The buoyant international castor oil prices helped the trade to flourish uninterruptedly. However, the problems related to farm production planning and its stabilization continued due to varying monsoon conditions from year to year. Drought posed a severe strain in meeting the export demand for castor oil. For example, during the years 1982-85, exports slumped primarily due to reduced production and not to slackness of demand. Consequent upon increasing prices, various new firms entered into the export business of castor oil.

4. CONCLUSION

This study has attempted to explain why castor became a prominent crop in Gujarat, India. The spectacular success of castor hybrids is explained through three phases of development, that is, breeding, adoption, and commercialization. The success of breeding can be ascribed to the followings. First, India possessed a wide spectrum of segregating materials which were required for developing new postulate lines; a large stock of germplasm entries which were required for developing superior quality male inbred line; and above all the breeders who put their whole-hearted efforts. Castor breeders produced castor hybrids which could yield 6-8 times more than the traditionally grown strains. This laudable jump in yield made castor attractive to farmers and as result castor became a competitive crop in Gujarat. Second, the breeding programme was strengthened and upgraded in terms of new techniques and importing of skills to breeders after the green revolution success and was carried out with continual feedback from farmers. It is now a recognized fact that the public investment made by the government in the agricultural research contributed significantly to agricultural growth and is estimated to be around 30 percent of the total growth.

Castor hybrids, when introduced to Gujarati farmers , were speedily adopted within 4-5 years of span of time. Almost 98 percent of total castor acreage in two major castor growing districts—Mehsana and Banaskantha—came under castor hybrids. The multiple advantages arising from these hybrids, in addition to their being economically competitive, attracted farmers to grow castor compared to other crops. These multiple advantages included: generating cash to meet farmers needs, requiring less supervision time; it can grow in less fertile soils as well in soils where other crops could not do well.

The critical factor in making adoption of castor hybrids speedier and persistent was the well-organized and reliable seed multiplication system in which quality was given utmost consideration. Although hybrid seed was very costly to farmers, yet farmers purchased it because it gave superior results in terms of yield and marketability. The success in adoption of castor hybrid was reinforced by the ready international market for castor oil to which India had access historically. But this alone was not enough, a marketing framework existed in Gujarat, pioneered by Jayant Oil Mill—a private firm which had been operating in Gujarat since 1950s with full-fledged processing, and research and development facilities. So farmers did not realize any problems in selling their produce. Since international castor oil market had been always buoyant, producers were guaranteed good prices. Hence, market risks were of lower order; rather, yield related risk due to weather and pest attack were more serious ones.

The interesting thing to note here is that there was spectacular success at each stage. A good breeding program resulted in high yielding hybrids which were readily adopted as producers found a ready market for their produce at reasonable prices. This may be sheer coincidence but it does tell us why some biotech innovations succeed and why others do not. The success to a great extent depends on: (1) the localising the innovation and making it amenable

to local needs and development of local infrastructure; (2) rapid adoption of the crops on farms which would require a good extension system; and (3) the conducive infrastructure and policy framework to incentivize the local farmers. In essence, this article concludes that mere development of variety or an innovation by scientists does not offer a guarantee of its success; rather adoption and commercialization are far more and equally important processes that must be ensured for achieving successful application of an agro-biotech innovation.[6]

NOTES

1. The beans market is small but growing slowly; the cake market is almost negligible.
2. Since 1986 castor acreage in Gujarat started declining. But there was a sharp drop from 209 thousand acres in 1987 to 68 thousand acres in 1988 —about 68% from the 1987 level. In addition to drought, severe incidence of wilt is understood to be also and important factor in explaining this fact. See Gujarat Agricultural University (1991).
3. Yield of GCH-4 was higher by 13 and 9 percent compared to GAUCH-1 and GCH-2, respectively. See Gujarat Agricultural University (1991).
4. The assumption behind this approach was that a bundle or package of interrelated innovations was better adopted than adoption of a single innovation. See Rogers (1971, pp. 171-172).
5. In Banaskantha district of North Gujarat, castor is grown in sand dominated soils. Many farmers believe that by growing castor on such soils leads to improved soil texture over time. Based on impressionistic survey of the area by author in 1995 and discussion with soil experts at SDAU.
6. The case of Quality Protein Maize or QPM is worth noting here. Millions of dollars were spent on developing this quality of maize at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico but without any efforts on adoption and commercialization phases. For details, see Brown F.N. (1995).

REFERENCES

Anonymous 2009. Castor Seed Production May Touch 11 Lakh Tons in 2008-9. *The Hindu*, February 16, 2009.

Anjani K 2011. Castor genetic resources: A primary gene pool for exploitation. *Industrial Crops and Products* 35(1): 1-14.

Ankineedu GK, Sharma D, Kulkarni LG 1968. Effects of fast-neutrons and gamma rays on castor, *Indian Journal of Genetics and Plant Breeding*, 28: 31-39.

Ankineedu G, Kulkarni LG 1965. Effect of irradiation on nature of fruit loculus in castor. *Indian Oilseed Journal*, 9(2): 37-43.

Brown FN 1995. Corn of Plenty. *Span*, 36(5): 30-32.

Classen CE, Hoffman A 1950. The inheritance of pistillate character in castor and its possible utilization in the production of commercial hybrid seed. *Journal of American Society of Agronomy,* 42: 79-82.

Evenson RE, Pray CE, Rosegrant MW 1999. Agricultural Research and Productivity Growth in India. Washington: International Food Policy Research Institute. *Research Report 109*, 1999.

Food and Agriculture Organization (FAO) (1961-97). *FAO Trade Year Book*, 1961-97.

Gopani, DD, Kabaria MM, Patel RH 1969. Study of sex reversion in castor. *Indian Journal of Agricultural Sciences*, 39(3): 255-58.

Gujarat Agriculture University 1991. *ICAR Quinquennial Review Team for Evaluation of Work of All-India Co-ordinated Research Project on Oilseeds 1983/84 to 1989/90*. AICORPO, Sardar Krushinagar, Gujarat, India. 1991.

Hegde, DM, Sujatha M, Singh NB 2003. *Castor in India.* Directorate of Oilseeds Research, Hyderabad, India.

Holfer CR, Strangland D 1958. Farmers attitudes and values in relation to approved practices in corn growing. *Rural Sociology*, 23: 1112-1120.

Kulkarni LG, Ankineedu G 1966., Isolation of pistillate lines in castor for exploitation of hybrid vigour. *Indian Journal of Genetics and Plant Breeding*, 26: 363-365.

Lavanya C, Chakrabarthy SK, Ramchnadram M, Rao CH, Raoof MA 2003. Development of wilt resistant pistillate lines in castor through mutation breeding, *Journal of Oilseeds Research*, 20: 48-50.

Pathak GN, Dikshit NN 1961. Expression of heterosis F1 hybrids of castor during germination and early seedling stages. *Indian Oilseeds Journal*, 5(4): 274-279.

Obiuaku LO, Hursh GD 1974. Farm practice adoption in the eastern states of Nigeria. *Agricultural Administration*, 10: 15-23.

Obiuaku LO 1979. Technical assistance and agricultural change in some Anabra state villages, Nigeria. *The Journal of Developing Areas*, 14: 43-54.

Rogers EM 1965/66. Mass media exposure and modernization among Columbian peasants. *Public Opinion Quarterly*, 29: 614-25.

Rogers EM 1962. *Diffusion of Innovations*. Glaney Edition. New York: Free Press.

Rogers EM, FF Shoemaker 1971. *Communication of Innovations: A Cross-cultural Approach*. 2nd Edition, New York: Free Press.

Sardarkrushinagar Dantiwada Agricultyral University (SDAU) (no date). Castor and Mustard Research Station: Achievements, From< http://www. sdau. edu.in.completed/castor/achivements. htm.> (Retrieved on 8 July, 2009).

Sindgi SS, Ansari ZA 1969. A dwarf mount in castor. *Mysore Journal of Agricultural Sciences*, 3(2): 115-23.

Subcommittee of the Rural Sociological Society 1952. *Sociological Research of Diffusion and Adoption of Farm Practices, RS-2.* Lexington: Kentucky Agricultural Experimentation Station.

Sujatha M 1996. *Genetic and Tissue Culture Studies in Castor (Ricinus communis L.) and Related Genera.* Ph.D. Thesis. Osmania University, Hyderabad, India.

Sujatha M, Reddy TP, Mahasi MJ 2008. Role of biotechnological interventions in the improvement of cas-

tor (Ricinus communis L.) and Jatropha curcas L. *Biotechnology Advances*, 26 (6): 424-435.

Tewari DD, Rao VM 1991. *Castor Economy : A Profile and Analysis of Indian and International Market*. New Delhi: Oxford and IBH.

Tewari DD 1994. Castor revolution: A biotechnological success. *Vatika: A Magazine of Indo-hybrid Seeds*. April, 1994.

Tewari DD 1995. Castor Revolution in Gujarat, India: What Made it Successful? *IIMA Working Paper No. 1254*.

Weis EA 2000. *Castor: Oilseed Crops*. Oxford, UK: Blackwell Science.

Whitney H, Johnson SR 1979. Population growth and the adoption of new technology in colonial Taiwanese agriculture. *The Journal of Developing Studies*, 15(4): 289-303.