Chapter 10
Castor

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10.1 Introduction

Castor (Ricinus communis L.) has the potential to become the premier vegetable oil crop for industrial oil production across the globe (Roetheli et al. 1990). Castor is an ideal candidate for production of high value, industrial oil feedstocks because of the very high oil content (48–60%) of the seed, the extremely high levels of potential oil production (500–1,000 l of oil/acre), and this plant's unique ability to produce oils with extremely high levels (80–90%) of ricinoleic acid (Brigham 1993). Additionally, the high potential yield and unique fatty acid composition of castor allows this oil to provide economically competitive feedstocks needed for the production of premium quality biodiesel, short chain aviation fuels, fuel lubrication additives, and very high value biopolymers (Geller and Goodrum 2004; Goodrum and Geller 2005; Roetheli et al. 1990). Because castor is not used for food and can be grown productively on marginal lands this crop represents a unique opportunity to expand industrial vegetable oil production on a global basis. Historically, commercial production of castor has been limited by concerns about the toxins found in castor seed, unstable global markets for the oil and the lack of efficient technologies to produce and process the crop (Brigham 1993). Development of improved production and genetic technologies will help ensure rural regions across the world can participate in the economic potential of this crop.

Most castor seed contains approximately 50% oil which is composed of 80–90% ricinoleic acid (12-hydroxy-cis-9-octadecenoic acid) (Atsmon 1989). This unique hydroxy fatty acid is used in a number of processes to create unique chemicals and polymers. Ricinoleic acid can be used in several bio-based fuels and industrial products. Pyrolysis of methyl ricinoleate generates methyl 10-undecylenate which can be processed to make Nylon 11 and a seven carbon product (heptaldehyde) that can be used as an octane enhancer for combustion engine fuels. Both of these products are highly valued industrial...
chemicals. A large variety of other reactions have been described that produce other high value products with great potential as biofuels and industrial polymers.

10.2 Origin and Domestication

Castor was probably one of the first crops cultivated by early man who used the oil extracted from the seed for a wide variety of uses including lamp oil (Weiss 2000). Castor is a member of the Euphorbiaceae family that is thought to have originated in Eastern Africa but has spread throughout the tropical regions of the world. Castor is a diploid \((x = 10, 2n = 20)\) with few if any natural polyploids (Moshkin 1986). Early taxonomists tried to classify castor \((Ricinus communis \text{ L.})\) into several subspecies based on phenotypic differences but most botanists now believe all castor belong in the same species. Castor accessions display significant differences in height, branching, color or growth habit, and many of these phenotypic traits are simply inherited (Peat 1928; Fig. 10.1) and most accessions will readily intercross (Atsmon 1989).

Fig. 10.1 Phenotypic variation for capsule spines in castor \((Ricinus communis \text{ L.})\) showing spineless capsules \((ss)\), reduced spines \((Ss)\), and normal spines \((SS; Peat 1928)\). Photos: A.D. Limmer, Texas Tech University

Most castor accessions produce monoecious flowers with the male (stamineate) flowers on the base of the inflorescence and the female (pistillate) flowers located on the terminal end of inflorescence (Atsmon 1989). However, the relative proportion and the location on the inflorescence of the male and female
flowers vary between different genotypes. Castor is highly cross pollinated with estimates on the High Plains of Texas ranging from 70 to 90\% (Brigham 1967a). Consequently, self pollinated seed can only be produced by sacking individual inflorescences prior to flowering (Atsmon 1989).

Historical summaries of castor production have been published by both Atsmon (1989) and Weiss (2000). In 2005 and 2006, India, China and Brazil produced the majority of the world’s castor oil with Ethiopia, Thailand and Paraguay contributing relatively minor amounts (Table 10.1). Annual total world production of castor seed exceeded one million tons during this period but average seed yields were never more than 1,200 kg/ha during this period. The volatility of castor oil prices and variability in production has made the international market for castor oil very unstable (Roetheli et al. 1990). Increasing demand for vegetable oils for biodiesel and other industrial applications have increased interest in improving the genetics and production of castor worldwide.

### Table 10.1 2006 and 2007 average castor seed production area, seed yield and total seed production in six major producing countries and worldwide (FAO-STAT 2008)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production area (ha)</th>
<th>Seed yield (kg/ha)</th>
<th>Total production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>805,000</td>
<td>1,063</td>
<td>861,000</td>
</tr>
<tr>
<td>China</td>
<td>255,000</td>
<td>961</td>
<td>245,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>184,231</td>
<td>701</td>
<td>130,565</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>14,500</td>
<td>1,034</td>
<td>15,000</td>
</tr>
<tr>
<td>Thailand</td>
<td>13,430</td>
<td>781</td>
<td>10,492</td>
</tr>
<tr>
<td>Paraguay</td>
<td>10,000</td>
<td>1,100</td>
<td>11,000</td>
</tr>
<tr>
<td>World</td>
<td>1,369,720</td>
<td>956</td>
<td>1,314,193</td>
</tr>
</tbody>
</table>

### 10.3 Varietal Groups

Castor has not been divided into varietal groups in recent times but most breeders recognize tall, late flowering types as tropical in origin. Those types which flower and mature quickly are usually adapted to either high altitude environments or more temperate latitudes in either the northern or southern hemisphere. There have been no reported barriers to intercrossing the two types and obtaining segregating populations.

### 10.4 Genetic Resources

A search of International Germplasm collections on the Bioversity web site combined with the USDA-ARS castor germplasm at Griffin, GA (USA) identified 12 major sources of germplasm and a total of 6,588 accessions (Table 10.2). Extensive germplasm collections are held in Brazil, China, Ethiopia, India, Kenya and the former USSR, but availability of these germplasm resources is not known. Additional castor germplasm can be obtained from
Table 10.2 Major germplasm collections of castor (*Ricinus communis* L.) as listed by the Bioversity International Directory (October 14, 2008)

<table>
<thead>
<tr>
<th>Country</th>
<th>Collection agency</th>
<th>Accessions reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>CENERGEN/EMBRAPA</td>
<td>360</td>
</tr>
<tr>
<td>Brazil</td>
<td>Centro Nacional de Pesquisa de Algodao (CNPA)</td>
<td>199</td>
</tr>
<tr>
<td>Brazil</td>
<td>Empresa Baiana de Desenvolvimento Agricola S.A.</td>
<td>528</td>
</tr>
<tr>
<td>Brazil</td>
<td>Instituto Agronomico de Campinas (I.A.C.)</td>
<td>200</td>
</tr>
<tr>
<td>China</td>
<td>Institute of Crop Science (CAAS)</td>
<td>1,689</td>
</tr>
<tr>
<td>China</td>
<td>Institute of Oil Crops Research (CAAS)</td>
<td>1,652</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Biodiversity Conservation and Research Institute</td>
<td>232</td>
</tr>
<tr>
<td>India</td>
<td>Region Station Akola, National Bureau of Plant Genetic Resources (NBPGR)</td>
<td>290</td>
</tr>
<tr>
<td>Kenya</td>
<td>National Dryland Farming Research Station, Kenya</td>
<td>130</td>
</tr>
<tr>
<td>Kenya</td>
<td>National Genebank of Kenya, Crop Plant Genetic Resources Centre, KARI</td>
<td>43</td>
</tr>
<tr>
<td>Romania</td>
<td>Agricultural Research Station Teleorman</td>
<td>66</td>
</tr>
<tr>
<td>Russia</td>
<td>N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry</td>
<td>423</td>
</tr>
<tr>
<td>Serbia</td>
<td>Maize Research Institute</td>
<td>69</td>
</tr>
<tr>
<td>Serbia</td>
<td>Institute of Field and Vegetable Crops</td>
<td>43</td>
</tr>
<tr>
<td>Ukraine</td>
<td>Institute for Oil Crops</td>
<td>255</td>
</tr>
<tr>
<td>United States</td>
<td>USDA-ARS-PGRCU</td>
<td>364</td>
</tr>
<tr>
<td>World</td>
<td>39 Institutes</td>
<td>6,588</td>
</tr>
</tbody>
</table>

Public breeders in South America including Brazil and Columbia. In tropical climates worldwide, castor can be found as an introduced plant species surviving as a weed in roadsides and non-cultivated areas. This feral castor can be a valuable source of germplasm especially for adaptation to localized diseases, pests and environmental conditions.

10.5 Major Breeding Achievements

10.5.1 Fatty Acid Composition

In 2004, a natural mutant of castor was isolated from USDA Plant Introduction PI 179,729 that had increased concentrations of oleic acid and reduced levels of ricinoleic acid (Rojas-Barros et al. 2004). This mutant produced seed oils with approximately 78% oleic acid and from 10.1 to 18.8% of ricinoleic acid. The increased levels of oleic acid appeared to be controlled by two independent genes (\(ol, MI\)) with epistatic interaction (Rojas-Barros et al. 2005). Incorporation of this mutant and other high oleic acid mutants in improved varieties may enhance the use of castor oil as a biodiesel feedstock.
Castor oil biosynthesis is a matter of considerable biochemical interest, due to the unusual chemical nature of the ricinoleate hydroxylation—a stereospecific, geometrically specific hydroxylation of a hydrocarbon chain, still an unrealized dream for the synthetic organic chemist. Although the cloning of the gene for this enzyme, oleoyl-12-hydroxylase, provided interesting insights into the production of ricinoleate and other uncommon fatty acids, transgenic plants that expressed the hydroxylase gene produced oils containing less than 20% hydroxy fatty acid (Broun and Somerville 1997).

Since the hydroxylase gene alone was not sufficient to elicit high levels of hydroxy fatty acid production, it seemed that there must be other enzymes that are required in order to achieve high ricinoleate levels in oil. Based on metabolomic studies of castor oil biosynthesis carried out by castor seed microsomes, there are several enzymatic steps that appear to be important for high ricinoleate levels (McKeon and Lin 2002). Further studies (Lin et al. 2002) indicated that 6-fold more ricinoleate is incorporated into triacylglycerol (TG) than oleate. This result indicated the final step in oil biosynthesis, diacylglycerol acyltransferase (DGAT), as the reaction that led to high ricinoleate content and minimal oleate in the oil. The diacylglycerol acyltransferase (DGAT) is a transmembrane enzyme that catalyzes the acylation of diacylglycerol (DG) to TG, using acylCoA as the source for the final acyl group. The DGAT reaction is widely considered to be the limiting step in oil biosynthesis, with considerable evidence indicating that altered DGAT activity levels dramatically affect the yield of oil (He et al. 2005). With the cloning of the DGATI from developing castor seed, it has been demonstrated that the activity and protein level of the cloned DGAT is closely correlated with the onset of oil biosynthesis in the seed (He et al. 2004). The castor DGAT enzyme displayed a 2-fold preference for using diricinolein vs. other non-hydroxylated fatty acyl DG. The acyl-donor for the DGAT reaction is produced by the acylCoA synthetase (ACS). One of several ACS cloned from castor displays a threefold preference for condensing ricinoleate vs. oleate with CoASH (He et al. 2007) suggesting the combined effect of the enzymes from the two cloned genes could result in a significantly higher incorporation of ricinoleate vs. oleate into oil. The question of how the castor seed produces an oil with such a high proportion of ricinoleate and a high oil content, approaching 60% continues to provide a challenge.

Understanding this process may ultimately lead to increased oil content and the ability to engineer the production of other uncommon and industrially useful fatty acids in the castor seed.

10.5.2 Castor Toxins

Ricin is a protein toxin found in the endosperm of mature castor seed that is capable of inhibiting protein synthesis by enzymatically destroying the ribosomes of eukaryotes (Khvostova 1986). The presence of ricin in the high protein
meal of castor remaining after oil extraction has historically reduced its value as an animal feed (Roetheli et al. 1990). Since ricin has the potential to be extracted and used as a chemical warfare and bioterrorism agent, the production and processing of castor has undergone increased scrutiny by international law enforcement agencies since the terrorist attacks of September 11, 2001 (Lowery et al. 2007; Franz and Jaax 1997). Development of castor cultivars with reduced levels of ricin would improve the economics of castor oil production, reduce the potential for accidental poisoning and eliminate the potential of ricin being used by terrorists.

Ricin has both an A and a B chain linked together by a disulfide bond. Both the A and B proteins have been DNA sequenced and appear to be initially produced by a single gene in castor (Halling et al. 1985; Tregear and Roberts 1992). Ribosome-inactivating proteins such as the ricin A chain typically contain a N-glycosylated, 32 kDa monomer (Olsnes and Pihl 1973). The A chain is attached to the cell surface by a the 34 kDa protein (B chain) (Roberts et al. 1985; Frankel et al. 1989). The ricin A chain has also been used in the production of immunotoxins which target specific diseases in humans (Ghetie and Vitetta 1994). Castor meal when applied as an amendment to greenhouse potting media has been shown to improve growth of okra (Hibiscus esculentus) and suppress root-knot nematode (Meloidogyne arenaria) (Ritzinger and McSorley 1998). Ricin has historically been degraded by exposure to high temperature for two or more hours (Roetheli et al. 1990). Ricin can also be degraded by exposure to concentrations of 3 mM sodium hypochlorite (Mackinnon and Alderton 2000).

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Castor seeds also contain a second toxin, Ricinus communis agglutinin (RCA₁₂₀) (Hartley and Lord 2004). RCA₁₂₀ is very similar in both amino acid sequence and structure to ricin (Hartley and Lord 2004). RCA₁₂₀ is composed of two A-chains and two B-chains linked together by disulfide bonds. This compound is much less toxic to mammals than ricin (Lowery et al. 2007).

Ricin makes an ideal target for genetic manipulation since this toxin appears to be controlled by a single gene that encodes both the A and B chains of castor (Halling et al. 1985). Conventional genetics were used to reduce the levels of ricin in dwarf-internode castor using crosses with two accessions from the Soviet Union, PI 258 368 and PI 257 654, which had been previously selected for reduced levels of ricin (Khvostova 1986). In subsequent segregating generations, individual plants were selected for dwarf-internode growth habit and reduced levels of ricin and RCA₁₂₀ using a radial immunodiffusion (RID) assay (Auld et al. 2003; Auld et al. 2001; Pinkerton et al. 1999). In 2003, twelve F₈ lines where intercrossed to develop a synthetic population adapted to mechanical harvest. In 2004 and 2005, this population was screened for semi-dwarf-internode growth habit and lack of shattering. This process developed a new experimental castor variety, 'Brigham' which has a ten fold reduction in the level of ricin.

A third toxic substance found primarily in the capsules and seed hulls of castor is the alkaloid, ricinine (Bukhatchenko 1986). Ricinine is thought to be a product of specific nitrogen synthesis and consists of a monocyclic derivative of
pyridine which carries a cyanide group. It appears to be a naturally occurring insecticide in castor that has a relatively low human toxicity. Russian researchers reported a negative correlation between the concentration of ricinine and oil in castor seeds. It also appears that drought conditions during seed maturation enhance the concentration of ricinine.

10.5.3 Castor Allergens

The allergy caused by exposure to the plant tissue and residue of castor has historically caused human health problems to those individuals working around or in close proximity to castor fields or plants processing castor seed across the globe (Panzani and Layton 1963). Most of those individuals expressing an allergic reaction have asthma like symptoms (Mercier and Panzani 1988). Cross-reactivity can occur with other species of plants within Euphorbiaceae (Layton et al. 1970). There has not been sufficient research to describe the chemicals produced by castor that cause these allergic reactions or germplasm screening to see if castor genotypes differ in their relative ability to cause allergic reactions in humans. However, the development of castor cultivars which do not cause allergic reactions would enhance production and processing of this crop.

10.5.4 Qualitative Traits

Capsule drop resistance caused by pathogens such as Botryotinia ricini (Godfrey) Whet. in humid areas of the USA is controlled by one or possibly two genes (Culp 1966). At least one of these genes appeared to be closely linked to the short pedicel trait. Researchers in both Russia and Trinidad have conducted exhaustive genetic studies that show the color of stems, leaves and capsules (Fig. 10.2), waxy coat on the stem and petiole, color of the hypocotyl and stigma of flowers, spines of the capsules, dehiscence of capsules, pedicel length, color and form of the seeds (Fig. 10.3), female sterility, flowering period, seed hull color, plant height and numerous other phenotypic traits are fairly simply inherited (Moshkin 1986; Peat 1928).

10.5.5 Quantitative Traits

In castor as well as in the majority of cultivated plants, the agronomic characteristics of primary economic importance are inherited in a quantitative manner including seed and total biomass production.
Fig. 10.2 Phenotypic variation in pod color of castor (*Ricinus communis* L.) caused by different combinations of the M (Mahogany) and G (Green) genes (Peat 1928). Photos: A.D. Limmer, Texas Tech University
Fig. 10.3 Phenotypic variation in seed shape, size and color of several different accessions of castor (*Ricinus communis* L.). Photo: A.D. Limmer, Texas Tech University

Hooks et al. (1971) evaluated the behavior of inbred lines of castor in a diallele cross using the method of Gardner and Eberhart (1966) and the procedures of Hayman (1954 and 1958). They observed that additive genetic effects were important in the initiation of bloom, the number of racemes per plant, and seed oil content. However, the number of nodes prior to flowering showed significance of additive genetic effects which agreed to the estimates derived by Swarnlata et al. (1984). Giriraj et al. (1974) evaluated a diallele cross of six geographically diverse cultivars and evaluated the length of the primary raceme, the number of capsules per primary raceme and 100-seed-weight. They showed that these traits also had very significant additive genetic effects. Solanki et al. (2003) evaluated the genetic effects of eight agronomic characteristics with similar results.

Solanki and Joshi (2000) evaluated a diallele cross between monoecious and female plants and found that additive effects were primarily responsible for the number of nodes, the length of the primary raceme, number of racemes per plant, number of capsules per primary raceme, 100-seed-weight, and total weight of seeds produced 120 and 240 days after the sowing. This study also
showed that the characteristics of days to 50% of bloom of the main cluster, 100-seed-weight and height of plants had high heritabilities indicating rapid selection efficiency.

Russian researchers have conducted extensive investigations on the inheritance of the components of seed yield and oil content in castor with similar results (Moshkin 1986).

10.6 Breeding Methods and Techniques

Castor is an often cross pollinated species with 14–45% self pollination under tropical conditions. In castor, the procedures for making artificial crossings and self-fertilizations are relatively easy and result in several seeds. Because of the reproductive biology of this species, the methods used to improve self-pollinated plants as well as the process of recurrent selection that is most often used on cross pollinated crops are feasible.

10.6.1 Mass Selection

Mass selection is most effective for characteristics with high heritabilities in populations with high levels of natural genetic variability such as heterogeneous land races. Two procedures are useful in increasing the efficiency of the mass selection in populations of castor: The self-fertilization of the selected plants to prevent cross pollination, and the use of controlled selection techniques to reduce environmental variation. Moshkin (1967) cites examples of application of the mass selection for enhancement of female flowers, in the selection for resistance to *Fusarium*, and reduction of plant height. Savy Filho (2005) used mass selection to develop IAC-38, an important dwarf castor cultivar in Brazil.

10.6.2 Individual Plant Selection with Progeny Tests

As in the mass selection, the selection of individual plants based on progeny tests is highly effective for the improvement of populations of castor with high levels of natural genetic variability. In the case of simultaneous selection for several characteristics, selection for the characteristics must be made using the highest possible number of self pollinated lines and be preceded first by the traits with high heritability that can be identified without the use of replicated trials. Subsequent selection and the final evaluation should be done on about 200 inbred lines arranged in a lattice experimental design with 3–4 replications in two or three locations and years. This type of testing allows selection for high seed and oil yield. In all phases of selection, the use of appropriate commercial check varieties will enhance selection
efficiency. Amaral (2003) successfully used the individual plant selection followed by progeny tests in developing the cultivar ‘Guarany’ of castor with increased seed yield.

10.6.3 Methods Involving Sexual Hybridization

When populations of castor with sufficient natural genetic variation for agronomic characteristics are not available, it is necessary to produce sexual hybrids between different lines or cultivars to generate sufficient genetic variability to support a selection program. The choice of the parents of these populations must be based on their agronomic performance within the targeted production region. In the case where there are several promising parents or cultivars it may be necessary to use a diallele cross design to identify those potential crosses with the greatest potential for creating highly performing sexual hybrid populations.

10.6.3.1 Pedigree Method

In the F2, F3, and F4 generations, self pollinated individual plants are selected to derive uniform lines. During this process, selection is practiced both between lines and within lines by selecting only the best plants within the best lines. By the F5 or F6 generation the inbred lines should have a high degree of homozygosity. These lines are then subject to a final evaluation using an experimental design and statistical interpretation of data taken over multiple locations and production years. Those inbred lines with superior performance that out-yield the check cultivars can be increased to create a new commercial cultivar.

The pedigree method works best when it is necessary to select simultaneously for several characteristics. Selection for the characteristics with the highest heritabilities should be made in the initial generations (F3 and F4), and the selection of quantitative characteristics in later generations. The pedigree method is limited by the selection of initial plants in the F2 generation needed to produce F3 inbred lines. This early generation selection process can restrict the full expression of individual plants genetic variability since F2 plants are highly heterozygous.

10.6.3.2 Bulk Method

The bulk method allows the hybrid population to segregate without artificial selection until the F5 or later generations (F6 or F7). The bulk method is most effective when the main objective of the program is to improve the adaptation of castor to stress conditions such as drought, acid soils, high levels of salt and resistance to diseases. After selection elite lines undergo a final evaluation as described for the pedigree method.
10.6.3.3 Single Seed Descent Method

The use of the single seed descent (SSD) method in the improvement of castor has not been frequently practiced but it offers two interesting aspects. It does not allow either natural nor artificial selection during the segregating generations but it does allow the increase of up to two generations per year using off season increases in either winter nurseries or greenhouses. In addition this techniques does not have as drastic reduction in the genetic variability in the \( F_2 \) or \( F_3 \) generations as the pedigree method.

10.6.3.4 Backcross Method

The backcross method of selection is most effective when there is a need to improve some simply inherited, qualitative characteristic in a commercial cultivar or promising elite line. The non-recurrent parent must have the characteristic absent from the recurrent parent. The method of backcrossing is especially effective in castor for the improvement of characteristics such as seed shattering, flower height, and disease resistance.

10.6.3.5 Recurrent Selection

Recurrent selection can be defined as successive cycles of selection and recombination of selected lines or individual plants. Recurrent selection has been more extensively used in species such as maize rather than in castor; Zanotto et al. (2004) had considered recurrent selection with use of inbred lines for the reduction of plant height in the cultivar 'Guarani'. The selection cycles occurred in two stages. In the first stage short plants were selected and self pollinated from the cultivar 'Guarani'. In the second stage, 180 self pollinated lines were evaluated for plant height in isolation and racemes of five plants of each one of the 30 selected lines were self pollinated by paper bags as described by Savý Filho (1999). After the selected lines had gone through at least five cycles of self pollination, the 30 selected lines were intercrossed and the harvested seed mixed to generate the cycle 1 seed. This procedure was repeated for four additional cycles of selection. According to Oliveira and Zanotto (2008) plant height was reduced by 28 cm, 13 cm, 19.9 cm, 11.7 cm and 3.4 cm, respectively, for the five cycles of selection. This process demonstrated the effectiveness of using recurrent selection with self pollination in castor.

10.7 Integration of New Biotechnologies in Breeding Programs

Allergen and ricin content are major issues that affect interest in production and processing of castor seed for castor oil. Since castor is not a food crop, one potentially fruitful approach to eliminating these noxious proteins is genetic engineering, to silence their expression during seed development. Both the primary allergen, 2S albumin, and ricin are expressed at a very high level during
seed development (Chen et al. 2004; Chen and McKeon 2005). With the proper choice of promoter and application of gene silencing techniques, gene expression can be suppressed up to 10,000 fold, which would be adequate for safe exposure to the seed meal.

However, genetic transformation of castor has proven to be highly challenging, as it is recalcitrant to efficient regeneration of stably transformed plants. The first report of transformed castor (McKeon and Chen 2003) described a vacuum infiltration technique using Agrobacterium carrying marker genes. Since then, an apparently more efficient method has been developed (Sujatha and Sailaja 2005). However, given the need to reduce ricin content by a factor of 10,000 and a similar reduction of allergen, there remains an urgent need to improve the efficiency of castor transformation. With such a method, not only could the noxious proteins be virtually eliminated, improvements that would benefit the growth and production of castor such as herbicide resistance, pest resistance, or monoracemic fruit-bearing could be made available. These traits would enhance the productivity of castor and simplify its harvesting. As a monospecific genus, Ricinus communis is somewhat limited in germplasm availability. The ability to introduce foreign genes into this non-food crop would have great potential to expand its growth habit and productivity.

10.8 Seed Production

Heterosis was shown to have a significant impact on days to flowering, racemes per plant, volume weight, oil content and seed yield indicating that increased seed and oil yields could be expected from the production of hybrids of castor (Hooks et al. 1971). Hybrids also appeared to have faster seedling emergence than open-pollinated lines (Brigham 1965). Composites have been used to capture a portion of this heterosis and increase genetic variability in castor (Brigham 1973). The production of hybrid seed in castor has been achieved using the fN-pistillate gene for female racemes and environmentally sensitive genes of interspersed-staminate flower by producing seed in locations with cooler temperatures (75-83°F) (Zimmerman and Smith 1966). In addition, two female-sterile characters (fs\textsubscript{1} and fs\textsubscript{2}) were identified by Brigham (Brigham 1967b). Commercial hybrids are now used in commercial production in Brazil, India and other parts of the world.

References


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