Experiences of Successful Castor Hybrid Seed Production in India

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Castor, a cross pollinated crop with sexual polymorphism which is highly sensitive to environmental conditions was successfully utilized to develop a two line breeding system. The present study is historically reviewed the development of hybrids variants and refinements in seed production technology facilitate to produce genetically high quality seed. Status of sex expression, developing pistillate lines and the historical achievements in heterosis breeding in India, seed production related issues and future outlook for castor hybrids have been broadly presented highlighting the role of hybrids placing India as a current global leader in production and productivity.

Introduction

The primary objective of plant breeding in crops is to develop superior varieties/hybrids. Several years of research efforts by plant breeders along with various subject matter specialists, infrastructural facilities, finance etc. required to breed an improved variety or a hybrid having better yield, quality, resistance to biotic and abiotic stresses and improvement in a specific trait. The benefit of superior varieties/hybrids can only be realized when they are grown commercially on large scale using true to type quality seeds. The value of pure improved seeds cannot be undermined. If the seed purity either genetic, physical including germination is not maintained, the superiority of improved genotypes is likely to be lost. whether a farmer produces a good crop or bad crop with the help of all the inputs at his command largely depends on the variety he has chosen and purity of its seed. Clearly, the seed of improved variety/hybrid should reach the farmer in pure and healthy state. To ensure this, systematic, scientific and elaborate seed programs are organized in most of the crops. In order to regulate the quality, the seed production is channelized into classes like, nucleus, breeder, foundation and Certified aided by certification standards fixed for different crops.

Castor Hybrid Breeding In India

Hybrid breeding in Castor (Ricinus communis L.) started at oilseeds research Station, Junagadh, Gujarat, India sometime in 1960 with release of GCH-3 in1968, a word first hybrid based on imported female TSP 10 R from Texas crossed with JI -15 inbred as male. Since then several hybrids all across India are developed and release by public and private R&D for commercial cultivation. The important hybrids from public institutions are listed below. (Table 1.)
Table No. 1. List of different castor hybrid and their parents

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Hybrid</th>
<th>Female</th>
<th>Male</th>
<th>Developed by</th>
<th>Year of Release</th>
<th>Area of Cultivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GAUCH-1*</td>
<td>VP-1</td>
<td>VI-9</td>
<td>GAU</td>
<td>1973</td>
<td>GUJ, RAJ</td>
</tr>
<tr>
<td>2</td>
<td>GCH-2*</td>
<td>VP-1</td>
<td>JI-35</td>
<td>GAU</td>
<td>1985</td>
<td>GUJ</td>
</tr>
<tr>
<td>3</td>
<td>GCH-4*</td>
<td>VP-1</td>
<td>48-1</td>
<td>GAU</td>
<td>1986</td>
<td>All India</td>
</tr>
<tr>
<td>4</td>
<td>GCH-5</td>
<td>Geeta</td>
<td>SH-72</td>
<td>GAU</td>
<td>1996</td>
<td>GUJ, RAJ</td>
</tr>
<tr>
<td>5</td>
<td>GCH-6</td>
<td>JP-65</td>
<td>JI-96</td>
<td>JAU</td>
<td>1997</td>
<td>GUJ, MAH, RAJ</td>
</tr>
<tr>
<td>6</td>
<td>DCH-32 (Deepi)</td>
<td>LRES-17</td>
<td>REC-5</td>
<td>IIOR</td>
<td>1998</td>
<td>All India</td>
</tr>
<tr>
<td>7</td>
<td>TMVCH-1</td>
<td>LRES-17</td>
<td>TMV-5</td>
<td>TNAU</td>
<td>1998</td>
<td>TN</td>
</tr>
<tr>
<td>8</td>
<td>DCH-177 (Deepak)</td>
<td>DCP-9</td>
<td>DCS-9</td>
<td>IIOR</td>
<td>1999</td>
<td>AP, TN, KT, MAH</td>
</tr>
<tr>
<td>9</td>
<td>RCH-1</td>
<td>VP-1</td>
<td>TMV-5-1</td>
<td>RAU</td>
<td>2000</td>
<td>RAJ</td>
</tr>
<tr>
<td>10</td>
<td>DCH-519</td>
<td>M-574</td>
<td>DCS-78</td>
<td>IIOR</td>
<td>2006</td>
<td>All India</td>
</tr>
<tr>
<td>11</td>
<td>GCH-7</td>
<td>SKP-84</td>
<td>SKI-215</td>
<td>SDAU</td>
<td>2007</td>
<td>All India</td>
</tr>
<tr>
<td>12</td>
<td>GCH-9</td>
<td>SKP-84</td>
<td>PCS-124</td>
<td>JAU</td>
<td>2016-17</td>
<td>GUJ</td>
</tr>
</tbody>
</table>

*In extensive use

GUJ= Gujarat, Raj= Rajasthan, MAH= Maharashtra, TN= Tamil Nadu, AP = Andhra Pradesh, KT= Karnataka

Seed Production of Castor In India
This is described as,
1. Female seed production
2. Male seed production and,
3. Hybrid seed production

Before the actual seed production is discussed, some information on sex forms, mechanisms and types of pistillate lines is described hereunder for better understanding seed production in castor. As also knowledge of important descriptor morphological traits is equally important for rouging activity.

Sex forms and pistillate sex mechanism in castor
Castor is highly wind cross pollinated monospecific and belongs to family, euphorbiaceae with diploid chromosome number 2n = 20. The extent of out crossing depends on wind direction and velocity. Sexually it is polymorphic species. The plant bears several sequential order branches and each branch terminates into fruit bearing raceme (spike). The sequential bearing has considerable influence on sex expression. The basic sex forms in castor are,

a. Monocious (M): The most natural occurring sex form of annual and perennial castor. The spike normally has 30 to 50% area in the base covered with male flowers and top portion with female flowers. In some cases both male and female flowers are found in interspersed fashion between above two.

b. Pistillate (P): This form occurs as rare recessive mutant with female flowers throughout the spike. The extent of female flowers can be 100% or little less than it with male flower at the base of raceme.

c. Interspersed Staminate Flower (IFS): In this case interspersed male flowers appear all across the spike as variant from pistillate.
d. **Sex Revertants**: This is a form where the female turns into monocious. The sex expression is highly influenced by environmental conditions and has been classified differently by different scientists. The important factors that affect sex expression (Lavanya, 2004) are,

1. **Temperature**: Important variable having strong influence on sex expression. Temperature more than 32° C is male promoting. In winter cool climate, the female flowers are more compared to hot summer climate.
2. **Poor fertility/Low nutrients**: Low nutrition and the poor fertility of soil leads to more male flowers to appear.
3. **Moisture**: Low moisture and water stress induces maleness.
4. **Age of plant**: Late order spikes have more male flowers compared to early order spikes.

The genetics of sex mechanism is complex polygenic inheritance. Sex expression is not a stable character in castor.

**Types of pistillate mechanism in castor:**

Three (N, S and NES) type of sex mechanism are reported.

A. **N Type**: The N type is governed by recessive sex switching gene and maintained by sib mating. In commercial hybrid seed production plots, normal monoecious plants have to be rouged out before anthesis leading to low genetic purity and high cost of rouging. The N type of pistillate source has been greatly improved leading to a female line, CNES-1 which requires little or no rouging (Classen and Hoffman, 1950).

B. **S Type**: S type pistillate line was obtained by selection within sex reversals at the Weizmann Institute, Israel and governed by dominant and epistatic effects. Sex reversals are plant variants which begin as female and revert to normal monoecism at any time after the first raceme and 10 or more racemes when grown as perennials. These perennial plants were considered as females, if grown only as annuals. Sex reversion is ontogenetically irreversible and is variegated where a part of the plant may still be pistillate while the other half is reverted to monoecious (Shiffriss, 1960, Ramachandram and Rangarao, 1978).

C. **NES Type**: NES pistillate type is a combination of both N and S type as it carries the homozygous recessive gene for pistillateness and environment sensitive genes for ISF. Production of ISF is not confined to any particular raceme order and temperature dependent (Ankineedu and Ganga Prasada Rao, 1973). NES type can be easily developed by transfer of a single recessive gene as compared to the polygenic complex of both dominant and epistatic S type. Pistillate lines like 240, NES 6, NES 17, NES 19, JP 65 are of NES type (Lavanya et al.,2006)

**Heterosis breeding**

Exploitation of heterosis in castor was initiated since 1960s even before the identification of pistillate lines. Heterosis over the standard checks was reported to vary from <20 to >100 percent over the years (Lavanya et al.,2006). However, heterosis observed in castor is not as substantially as high as in other cross-pollinated crops due to its inherent ability to self-pollinate, especially in the primary spike. Initial reports suggested heterosis for germination rate, formation of leaves and plant height in early seedling stages, leaf number and leaf area index. Attempts to exploit hybrid vigour through monoecious lines were not successful due to laborious process of emasculation. Although heterosis for total seed yield occurred, there was no significant increase in the percentage of female flowers on racemes (Lavanya et al., 2006).

Heterosis was high for seed yield followed by number of capsules on the main raceme and 100 seed weight. Heterosis and heterobeltiosis for seed yield per plant was due to heterosis for capsules on main raceme, length of pistillate region of main raceme, effective branches per plant and
seed yield of main raceme while heterosis for seed yield was associated with number of effective spikes per plant (Lavanya et al., 2006).

A contradictory opinion was that the magnitude of heterosis was mainly due to the highly female expression inherited from the dominant female nature of the S type pistillate line (Moshkin, 1986; Atsmon, 1989) which contribute to the raise in seed yield. Genetic basis of heterosis of seed yield is due to the factors other than heterosis per se like the improved parental lines for spike density, highly female spikes, earliness, short stature, etc (Atsmon, 1989).

Heterosis was mainly manifested in parental lines of contrasting morphological characters like dwarf plant type with condensed nodes, cup shaped leaves in pistillate lines vs normal tall plant type, elongated nodes, flat leaves in male lines (Lavanya et al., 2006). Per se performance and average heterosis in dwarf x tall crosses were higher to the parents involving moderately tall x tall and tall x dwarf crosses. Heterosis for seed yield was correlated with heterosis for main spike length and capsules / primary spike when one of the parents was tall.

VP-1 is the first stable pistillate line developed in Gujarat from the segregation of a double cross between F2 of JHB 48 (JP 5 x 26006) x JHB 67 (TSP 10R x 719/1) with distinct morphological characters like green stem, triple bloom, cup shaped leaves, condensed nodes, long primary spike with spiny capsules (Lavanya et al., 2006). Development of stable pistillate lines from S-type is based on selection from late order of revertants. Selfed plants of the second and third orders of reversion yielded more number of pistillate plants than sibbed pistillate and selfed first order revertants. Selfed plants of the 10th order of reversion yielded nearly all pistillate plants in their progenies. Several pistillate lines viz., SKP 4, LRES 17, DPC 9, DPC 13, DPC 14, SKP 120, SKP 84, MCP 1-1, JP 58, JP 65, Geeta, etc., were developed using VP-1 source of pistillate expression (Lavanya et al., 2006).

The hybrid GCH 3 was an instant success due to its high yielding ability (88% yield increase over S-20), drought resistance, medium maturity (140-210 days) and high oil content (46.6%). Though the hybrid was released for irrigated castor growing areas, it became popular even in rainfed castor growing areas. Due to its early maturity Gujarat farmers of Mehsana district were able to take up castor as a kharif crop followed by a second crop of either wheat or summer pearl millet wherever irrigation facilities were available.

The research efforts initiated during the latter part of 70’s resulted in the development of first wilt resistant hybrid GCH 4 (VP-1 x 48-1) released in 1986 for commercial cultivation in entire castor growing areas of the country (Lavanya et al., 2006). It is superior in yield over GAUCH 1 (13%) and GCH 2 (9%). It is well adapted to both rainfed and irrigated castor growing regions of the country. This hybrid, when grown as a horticultural crop under intensive cultivation with high inputs near riverbanks of Khisurpuri regions of Ahmedabad district, gave a seed yield of more than 9 tonnes/ha which is still a world record (Lavanya et al., 2006).

Susceptibility of VP-1 to Fusarium wilt led to efforts on diversification of pistillate source through conventional and mutation breeding approach. Among the 14 hybrids released so far in the public sector system, GCH-4 is high yielding (1200-2200 kg/ha), suitable for rainfed and irrigated conditions, tolerant to wilt and still the most popular hybrid even after 24 years of release. It is now being replaced by the latest high yielding hybrid GCH-7 (3000 kg/ha) which is resistant to both Fusarium wilt and reniform nematode complex.

**Seed production technology**

Success of any seed production technology depends on the availability of pure, stable parental lines, heterotic hybrid combination and standard seed production technology. The cross-pollinated nature of the crop and complexity of sex and its high sensitivity to genotype-environment interactions (climate, nutrition, management, etc.) further make seed production in castor complicated. Stages of seed production like foundation, certified hybrid seed production in castor are highly season bound to exploit the environmental sensitive nature of the parental lines.
Foundation seed production of both female and male lines is done in summer season while the certified hybrid seed production is sown as an early rabi crop from September second fortnight to October second fortnight. Initial delays in popularization of castor hybrids were mainly associated with inherent problems like low genetic purity in commercial hybrids. This was attributed with the instability of parental lines, improper rouging and insufficient isolation distance leading to poor seed quality and rejection of seed lots by certifying agencies prior to 2002-03 (Lavanya et al., 2006).

The breakthrough in successful cultivation of castor hybrids was mainly possible due to the interventions in seed production technology leading to availability of high quality hybrid seed to the farmers. Major success in hybrid breeding technology is the significant modifications in the seed production technology by increasing isolation distance from 150 to 300m, and imposing refined method of seed production technology of the pistillate lines in place of conventional method of seed production (Lavanya and Solanki, 2010, Zaveri, 2009).

The conventional or traditional method of maintenance of pistillate plants relies upon maintaining 20 to 25% monoecious or revertant plants as a pollen source resulting in high proportion of monoecists, 40-65% early revertants in certified hybrid seed under extreme conditions (Ramachandram and Ranga Rao, 1988; Prabakaran et al., 2009). This leads to high cost of rouging and low genetic purity in the female line. Sowing season for conventional method is recommended as kharif or post rainy season. The estimated loss by adopting conventional method of seed production owing to rejection of seed lots based on the low genetic purity was nearly 100 crores of rupees to the seed producing farmers in Gujarat alone during the last two decades.

The method has been modified or refined by allowing the environmentally sensitive interspersed staminate flowers (ISF) as the pollen source in summer season with an isolation distance of 1000m (Ramachandram and Rangarao, 1978; Prabakaran et al., 2009). There is a spectacular improvement in seed production programmes due to the implementation of refined method of maintenance of pistillate line and doubling of isolation distance (150 m to 300 m) for certified hybrid seed production. The mean percent rejection of seed lot in GCH-4, during 1992-2002 was 43% (971.6q) of the total seed lot which reduced to 29.5% (3130.7q) in 2003-08 after the implementation of 300 m isolation distance in 2002-03. (Zaveri, 2009). A study conducted by Navbharat Seeds, Gujarat using 17 lots of GCH-4 for grow out test indicated that rejection of seed lots in modified method has significantly reduced to 5.9% compared to 23.5% in conventional method (Lavanya and Solanki, 2010).

Future outlook

Development of cryptic hybrids as in maize was proposed in a recent paper on castor (Liv et al., 2012). Clean Genome Technology for developing castor hybrids with a claim of very high productivity need to be seen for its field performance. Indian castor researchers both in private and public need to be alert for these advanced technologies and competition that is likely to arise from China and Brazil. Short and medium duration kharif hybrids with Botrytis resistance are likely to enhance the area under rain-fed castor not only in Andhra Pradesh but also in non-traditional areas such as Madhya Pradesh and Maharashtra. Short duration hybrids targeting primary spike alone may also have potential in Orissa and other North Eastern States fitting in to the cropping system after kharif. There is a tremendous scope of exploiting available genetic diversity to develop new parental lines with stable sex expression to achieve higher levels of heterosis.

Challenge of lepidopteron pests particularly semilooper, spodoptera and the capsule borer haunts the future of castor expansion. The Directorate of Oilseeds Research has initiated research on developing markers for biotic and abiotic challenges with a hope to develop Marker Assisted Hybrids in the near future. Castor being non-edible crop, exploitation of novel approaches including transgenic approach for developing new generation hybrids is worth-while exploring. Diversifying sources of wilt resistance and drought tolerance in parental lines shall be a priority.
Castor seed oil (45-55%) has a unique fatty acid, ricinoleic acid (80-90%) which is indispensable in the manufacture of more than 250 industrial products (Suresh, 2009). However, industrial recovery of ricinoleic acid hovers around 85-87% in hybrids. There is a need to focus research on developing parental lines of castor hybrids with higher recovery of ricinolic acid adding industrial value. Developing CMS based hybrids and low ricin hybrids need a fresh look based on demand and available resources. Genetic purity of parental lines, maintenance breeding, testing new parental lines for seed production systems with current challenges of changing temperature and moisture regimes are the key factors for hybrids success.

References