# Chapter 2
# Breeding Major Oil Crops: Present Status and Future Research Needs

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**Abstract** Oils extracted from plants have been used predominantly as edible oil. Soybean, peanut, rapeseed mustard, sunflower, safflower, *Sesamum*, linseed, castor and cotton seed are predominant oil crops. Global status of nine major and minor oil crops has been discussed which includes their classification, contribution, major growing countries and objectives. Major objectives in oil crop improvement are enhancement of seed and oil yield, quality of oil according to its use, i.e. edible or industrial uses, breeding of varieties which fit in different cropping systems and breeding biotic and abiotic stress resistant/tolerant varieties. Achievements in varietal development programme of nine oil crops in India have also been discussed and future research needs to meet the increasing demand have also been highlighted. This review describes developments in use of biotechnological tools in seven edible oil crops, namely, *Brassica*, soybean, sunflower, groundnut, *Sesamum*, linseed and safflower and also highlights the prospects of using markers in genetic improvement of these crops. Molecular markers reported for genetic diversity assessment, mapping and tagging genes/QTLs for different qualitative and quantitative traits and their use in marker-assisted selection have been presented.

**Keywords** Oil crops • Breeding objectives • Research needs • Gene mapping • Genome maps • Molecular markers

## 1 Introduction

Oils extracted from plants have been used since ancient times and have been exploited in many ways. Predominantly, it is used as edible oil. It is also used in medicines and pharmaceuticals, industries, biodiesel, pet foods and component of

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many other products. Dietary fat, a concentrated source of energy, supplies about half of the calories and carries fat soluble vitamins. Its by-products are being used as feed, manures and find uses in many other industrial and domestic uses. There is large number of oil crops grown worldwide. Amongst them soybean, peanut, rapeseed mustard, sunflower, safflower, *Sesamum*, linseed, castor, cotton seed are predominant. Total world's oilseed production from major oil crops was 423.55 mt from 205.08 million hectares (mha) area during 2009–2010 (http://www.fas.usda.gov/psdonline). The leading countries in oilseed production are USA, Brazil, Argentina, China and India. The crop wise pretext is discussed here.

## 2 Soybean

Soybean (*Glycine max* L. (Merrill), $2n=40$) a *Papilionaceae* family plant is the most important grain legume in terms of production and international trade. In addition to high protein content (40%), the soybean seeds contain 18–23% oil and thus add to the importance of the species as an edible oil yielding crop. Soybean accounted for 57% of the world's oilseed production. Soybean has the longest recorded history of cultivation among crop plants dating back to Chou dynasty in 664 BC and northern China is considered as the centre of its domestication. In India, this crop was grown in isolated areas since ancient times. The feasibility trial conducted during 1963–1964 with the introduced material from the USA marks its modern cultivation in this country. Systematic breeding programme was initiated at Pantnagar and Jabalpur and later at many other centres, which led to the development of a large number of improved varieties. Introduction of this temperate crop to sub-tropical climatic conditions made it more vulnerable to problems like seed longevity, poor growth rate due to changed photoperiod, various biotic and abiotic stresses, etc (Hegde 2009a).

### *2.1 Objectives*

The most important breeding objective is yield enhancement. Since this crop is mainly grown under rainfed condition, genetic enhancement of yield under rainfed situation has been a major challenge. Tailoring of high yielding plant type includes the desirable features like determinate to semi-determinate growth habit, erect and non-lodging with 100–105 days maturity to escape moisture stress. On the other hand, some hybrids are reporting around 20% heterosis and the male sterile systems for seed production are available; however, the efficient pollen transfer mechanism is a major obstacle in exploitation of hybrid vigour in soybean. Genetic variability for oil quantity and quality is available. Indirect selection for seed density and specific gravity would lead to high oil yields. Beside quantity, varieties with high oleic acid and low linolenic acid need to be developed.

Other important objective is to enhance seed longevity. Soybean is known for its poor storability. Due to vulnerable position of its embryo, it is highly sensitive to injury. Deterioration in seed quality is very fast particularly under tropical climate during storage. Many small seeded varieties have better germination than bold seeded ones. This undesirable association needs to be broken and is possible through breeding. Although bold seeded genotypes with high seed longevity have also been reported. Varieties which are resistant to mechanical damage and maintain more than 70% germination after 8–9 months of ambient storage need to be developed. Accelerated aging, electrical conductivity and vigour tests are generally used for screening and identification of promising lines from the breeding material.

Stability of performance is of utmost importance in soybean. Early maturity and photoperiod insensitivity are prerequisites for better adaptability and its suitability to different cropping systems. Early maturity would further help in combating the terminal drought through escape mechanism. Host plant resistance against diseases like rust, root rot, stem canker, bacterial blight, yellow mosaic virus and insects like stem borers, gram pod borers and sting bug would further help in stabilizing the yields.

## 3 Brassicas

The *brassicas* commonly known as rapeseed mustard are important group of edible oils and vegetables crops belonging to *Brassicaceae* or *Cruciferae* family. This group comprises of six cultivated species, namely, *Brassica campestris*/*rapa* (2*n*=20, AA), *Brassica nigra* (2*n*=16, BB) and *Brassica oleracea* (2*n*=18, CC) are diploids; *Brassica juncea* (2*n*=36, AABB), *Brassica napus* (2*n*=38, AACC) and *Brassica carinata* (2*n*=34, BBCC) are digenomic tetraploids, which evolved in nature following hybridization between the constituent diploid species. Rapeseed mustard is the third most important source of vegetable oil in the world and is grown in more than 50 countries across the globe. China, Canada, India, Germany, France, UK, Australia, Poland and USA are the major cultivators of different species. The estimated area, production and yield of rapeseed mustard in the world during 2009–2010 was 30.74 mha, 59.93 mt and 1.95 t/ha, respectively. Globally, India account for 21.7% area and 10.7% production (USDA 2010). During the last 7 years, there has been a considerable increase globally in productivity from 1.54 t/ha in 2003–2004 to 1.95 t/ha in 2009–2010 and production from 39.42 mt in 2003–2004 to 59.93 mt in 2009–2010. *Brassica rapa, B. napus* and *B. juncea* are grown predominantly for oil and seed meal. India is the second largest country in rapeseed mustard production and more than 85% of its area under rapeseed mustard is occupied by Indian mustard *B. juncea* (L.) alone. At present, the maximum average productivity in our country is around 1.19 t/ha (2008–2009) which is much below than that of the other *Brassica* growing countries. In UK, France and Germany, the average productivity of rapeseed mustard is two to threefold higher than India and the world average is also more than

50% higher than that of India. A reason for this low productivity is mainly the poor stability of performance despite availability of improved varieties with high yield potential. Production and productivity statistics of past decade and their relationship with weather parameters and disease outbreak indicates that the main reasons of fluctuation are unpredicted rainfall (drought or untimely rains), high temperature at different growth stages and infestation of diseases and insect pests like white rust, *Alternaria* blight, *Sclerotinea* stem rot, powdery mildew, downy mildew and aphid.

### 3.1 Objectives

For breaking the yield barrier, population improvement programme was followed involving diverse parents. Through the intervention of biotechnological tools, yield QTLs are to be identified and can be introgressed in improved backgrounds using marker-assisted selection (MAS). Poor plant stand is one of the factor for non-realization of actual yield potential in timely sown crop, which is mainly because of high temperature at seedling stage. If late sowings are done, high temperature at reproductive stage leads to forced maturity resulting in reduced yield with low oil content. Hence, genotypes having inbuilt tolerance to high temperature at seedling stage as well as terminal heat tolerance are the need of hour. Mustard being a crop of marginal lands, genotypes with inbuilt mechanism to yield higher under scanty moisture conditions are required. Hence, genotypes with high water use efficiency can be exploited. Fertilizers applied are not used efficiently; hence development of high fertilizer use efficient lines is also required. Salinity is becoming one of the limiting factors in *Brassica* production which needs attention. Genotypes tolerant to heavy metals and enhanced $CO_2$ utilization also need attention in the times to come.

There is no resistant sources available for *Alternaria* blight, *Sclerotinea* stem rot, aphid and painted bug, and trans genes are the option for development of transgenic *Brassica* having inbuilt resistance for these biotic stresses. Pyramiding the genes/QTLs for various biotic and abiotic stresses using the plant biotechnology tools has to be explored.

It is realized that the improvement through the use of conventional breeding approaches is tending to level off, since these breeding approaches do not mobilize sufficient amount of genetic variation, whereas hybrids offer an opportunity for mobilizing greater amount of genetic variability and available high heterotic response in Indian mustard. In order to increase the yield potential of *Brassica,* hybrids are one of the most viable options for breaking the yield barriers. Presently, there is about 15% yield increase in case of hybrids. Diverse cytoplasmic sources may give high heterotic hybrids under three line hybrid development programme. For saving the time, the introgression of CMS/restorer system to the identified combiners should be taken up through marker-assisted backcross breeding. Genotypes with high harvest index, basal branching from ground level, long and higher primary and secondary branches with synchronous higher number of siliquae are desirable for yield enhancement. Quality is an important concern in the times to come. Breeding of Canola types Indian mustard varieties is the need of the hour to make this crop globally competent. Oil content also needs to be enhanced from the average 38–39% to that of >45%.

## 4 Sunflower

Sunflower (*Helianthus annuus* L., 2*n*=34) an *Asteraceae* family plant is native to the temperate North America, which is the centre of diversity for this important edible oil-yielding species. Sunflower is grown in all continents. Europe and America account for nearly 70% of total area and 80% of total production (Damodaran and Hegde 2007). Its cultivation in Asian countries is comparatively recent. Asia accounts for nearly 20–22% of the global sunflower and contributes to about 18% of the production. The productivity of sunflower in Asia is about 1.0 t/ha which is lower than the world average. India is the largest grower of sunflower in the Asian continent. This is a short duration crop which is adaptable to a wide range of agro-climatic situations, having high yield potential, suitable for cultivation in all seasons due to its day neutral nature and can fit well in various inter and sequence cropping systems. However, the average yield of this crop in India is lowest; it is less than half the world average, and static hovering around 0.5–0.6 t/ha. Emergence of new diseases and large climatic variations, particularly recurrence of drought stress during critical growth stages, has affected stability and yield on a regular basis. Therefore, there is a need to reorient the breeding objectives considering the adverse agroecosystems or target population of environments where the crop is grown.

### *4.1 Objectives*

Hybrids in sunflower have recorded two times higher seed yield than the open pollinated varieties. Narrow genetic base is the major bottleneck in further improving the yields. Release of large number of hybrids in the past has broadened the base of hybrids in the country. Still there is need to improve the diversity of the parental lines to achieve the higher level of heterosis in sunflower. Diversification of male sterility source may also help in improving stability of the hybrids. Beside seed yield, oil content, which is hovering between 35 and 40% in hybrids, is also equally important and needs to be improved up to 45% so that this crop may be made more profitable.

For stabilizing the yields, host plant resistance against major diseases like downy mildew, *Alternaria* leaf spot, rust and viral necrosis and insects like capitulum borer, tobacco caterpillar, Bihar hairy caterpillar, green semilooper, cabbage semilooper, cut worms, leaf hoppers and thrips is required in the parental stocks for their exploitation through hybrids. Introgression of resistance against major insects like *Heliothis* and *Spodoptera, Bt* sunflower needs to be developed. Identification of resistance/tolerance sources for drought related traits and their subsequent transfer in the improved genetic background would help in achieving the stability of production in diverse rainfed areas.

Being a crop of all seasons this crop is grown continuously after harvest of the earlier one which has led to micronutrient deficiency, toxicity and complex of diseases and insect pests leading to low yields. Breeding/management input is required to address this issue.

## 5 Groundnut

Groundnut (*Arachis hypogaea* L., $2n=40$), a *Papilionaceae* family plant, is an allotetraploid having South American origin. Recent studies have indicated that it originated in northern Argentina or southern Bolivia from hybridization between the diploid wild species *Arachis duranensis* and *Arachis ipaensis*. It is the fourth most important oilseed crop in the world, grown mainly in tropical, subtropical and warm temperate climates. It is presently cultivated in 108 countries of the world. Asia with 63.4% area produces 71.7% of world groundnut production followed by Africa with 31.3% area and 18.6% production, and North-Central America with 3.7% area and 7.5% production. Important groundnut producing countries are China, India, Indonesia, Myanmar, Thailand and Vietnam in Asia; Nigeria, Senegal, Sudan, Zaire, Chad, Uganda, Republic of Ivory Coast, Mali, Burkina Faso, Guinea, Mozambique and Cameroon in Africa; Argentina and Brazil in South America and USA and Mexico in North America (Hegde 2009a). Its seeds are a rich source of edible oil (43–55%) and protein (25–28%). About two-thirds of world production is crushed for oil and the remaining one-third is consumed as food. Its cake is used as feed or for making other food products and haulms provide quality fodder. In India, it ranks third after soybean and *Brassica*s. Domesticated groundnut exhibits a considerable amount of genetic variation for morphological traits such as growth habit, seed colour and size, number of seeds per pod and patterns of flower production on the stems. Besides, variation exists for the nature of reaction against pathogens and insects.

### *5.1 Objectives*

The major breeding objectives in this crop are development of high yielding cultivars of suitable duration to escape moisture stress with resistance to various biotic stresses (foliar diseases like rust and early and late leaf spots and aflatoxin contamination by *Aspergillus flavans*, pod and stem rot, etc.) and tolerance to different abiotic stresses (moisture stress). Continuous efforts have yielded genetic resistance for these diseases. Short and medium duration and confectionery type varieties with multiple tolerance/resistance have been developed by ICARISAT as well as NARS in India. Significant progress has been seen in understanding and underlying the mechanism of drought tolerance in groundnut. As it has been established that yield under water limited conditions is a function of transpiration (T), transpiration use efficiency (TE) and harvest index (HI), large exploitable genetic variation has been observed in germplasm of groundnut for these traits (Rachaputi and Wright 2003). There is a need to develop a selection index integrating T, TE and HI with appropriate weights for use as selection criteria in a breeding programme (Chandra et al. 2003). In addition to resistance/tolerance to the prevailing biotic and abiotic stresses, a variety for becoming successful should be in harmony with the edaphic and climate factors of ecosystem. The duration of the variety, irrespective of its growth habit should match with the period of soil moisture availability particularly under rainfed situations. Novel techniques such as genetic transformation, molecular markers added selection and gene transfer from alien sources need to be exploited more for making an impact on groundnut research.

# 6 Sesamum

*Sesamum* (*Sesamum indicum* L. $2n=26$) belongs to the family *Pedaliaceae* which has a wide distribution, covering tropical Africa, Madagascar, Arabia, India, Sri Lanka, tropical Australia and a few of the eastern islands of the Malayan Archipelago. It is an ancient oil yielding crop. Due to the presence of diverse wild species, Africa is considered the primary centre of origin, while India and Japan are considered as the two secondary centres of origin of this crop. India, China, Sudan, Mexico, Turkey, Burma and Pakistan are the important *Sesamum* producing countries. India ranks first, both in the area and production of this crop in the world. The annual area put under it in India is about 2.5 mha (45% of the world hectarage) and the total production is nearly 52,000 t. Its seeds contain 45–52% of edible oil (Hegde 2009b).

## *6.1 Objectives*

Higher yields, improved plant architecture, adapted crop duration, resistance to diseases and pests and indehiscent capsules are the major objectives in this crop. The degree of dehiscence is a cultivar characteristic and is of great importance for mechanized harvesting. The leaf eating caterpillar (*Antigastra catalaulmlis* Dup.) and the gallfly (*Asphondylia sesalili* Felt) are the serious pests of *Sesamum*. Stem and root rot (*Macrophominia phaseoli* Maubl.), phyllody (virus, mycoplasina), bacterial leaf spot (*Pseudomonas sesami* Matkoff) and leaf curl are the important diseases of this crop which needs genetic interventions. Among the various options available for increasing the productivity, heterosis breeding is perhaps the most important way for the vertical yield increase in this crop. China has the distinction of successful exploitation of heterosis in this crop at commercial level with hybrid developed through hand emasculation, GMS/CMS systems and exhibited the yield potential up to 3.0 t/ha. The programme on development of CMS lines through interspecific hybridization needs to be strengthened for exploiting some workable CMS system in this crop for hybrid development programme. This crop has been ignored for value addition to its oil. The development of varieties with low or zero anti-nutritional factors like oxalic and phytic acids needs attention for its value addition. In addition, the efforts should also be made to develop low free fatty acid (<2%) varieties of *Sesamum*. Increase in oil content is also one of the important components in varietal improvement of this crop.

# 7 Linseed

Linseed (*Linum usitatissimum* L., $2n=30$) is a diploid, self-pollinated and homozygous species of *Linaceae* family. This genus comprises mostly herbs and shrubs in tropical and subtropical region. It is an important oilseed crop grown both for seed and fibre. It is an industrial oilseed crop and its each and every part has commercial and medicinal importance. India ranks second after Canada in terms of area and is at the fourth position in production after Canada, China and USA. The productivity of this crop is very low as it is grown under input starved and moisture stress conditions. The major diseases of this crop are wilt, rust, powdery mildew and *Alternaria* blight. Amongst the insects, bud fly is causing lot of losses to this crop.

## *7.1 Objectives*

The average productivity of this crop at national (0.4 t/ha) as well as at global level (0.85 t/ha) is low in comparison to other oil crops like soybean, rapeseed mustard and groundnut. Hence, the breeding strategies for yield enhancement need immediate attention. Oil content is one of the important components in oil crops and it is around 28–30% in linseed varieties which has ample scopes for enhancement. Linseed oil has more than 50% linolenic acid which is fit for its industrial application but where linseed oil is being used as edible oil, the linolenic acid needs to be reduced. Efforts in this direction have already been successful with the development of low linolenic acid varieties LINOLA in Australia in 1984 and SOLIN in Canada in 1990. In India too national linseed programme in collaboration with BARC, Mumbai has developed some genotypes with less than 1% linolenic acid. Hence, the breeding efforts are needed further for development of low linolenic acid varieties, the oil of which can be widely used as cooking oil. As linseed is highly nutritious, efforts are needed to reduce its anti-nutrient components and also bio-convert its less acceptable omega-3 ALA into acceptable SDA. For achieving this objective, in addition to the conventional breeding, the biotechnological tools like marker-assisted breeding and genetic engineering may also be employed. Moisture stress being one of the major constraints, the varieties with inbuilt water stress tolerance may be given more emphasis to enhance and stabilize the productivity for making this crop more remunerative. More concerted efforts for development of varieties resistant to different diseases like wilt, rust, powdery mildew and *Alternaria* blight are also required by using the different resistant donors already available in this crop.

## 8 Safflower

Safflower (*Carthamus tinctorius* L., $2n = 24$) is a member of the family *Compositae* or *Asteraceae*, cultivated mainly for its seed, which is used as edible oil and as birdseed. Traditionally, the crop was grown for its flowers, used for colouring and flavouring foods and making dyes, especially before cheaper aniline dyes became available, and in medicines. Oil has been produced commercially and for export for about 50 years, first as an oil source for the paint industry, now for its edible oil for cooking, margarine and salad oil. Over 60 countries grow safflower, but over half is produced in India (mainly for the domestic vegetable oil market). Production in the USA, Mexico, Ethiopia, Argentina and Australia comprises most of the remainder. China has also significant area under safflower (Li and Hans-Henning 1996). Varietal improvement programme on safflower was initiated during 1935 in India which resulted in release of some varieties specific for limited areas. The All India Coordinated Research Project on Safflower was established in 1972 which led to the development of 29 varieties and hybrids for different safflower growing areas of the country (Hegde 2009a).

### *8.1 Objectives*

The average productivity of safflower is still low (0.65 t/ha) in comparison to 1.4–2.3 t/ha in other parts of the world. This necessitates in breeding varieties with enhanced yield potential. With the availability of GMS systems in this crop, hybrid development has become reality in 1997. Now the cytoplasmic genetic male sterility system is a new hope to develop the high yielding publicly acceptable hybrids surpassing the problems associated with GMS-based hybrids. Safflower hybrids can offer greater stability in less favoured environments subject to biotic and abiotic stresses. It is evident from high yield performance of safflower hybrid DSH 129, which yielded about 18% higher seed yield than varieties under wilt, moisture and P stress conditions under large-scale field demonstrations (Reddy et al. 2004). There is a possibility of development of hybrids with high oil content, disease/insect resistance and abiotic tolerance by choosing the appropriate parental lines.

Varieties tolerant to drought will also definitely help in enhancing the productivity of this crop as about 80% reduction in the yield of safflower has been reported due to prolonged moisture stress. For immediate future need, the exploration of germplasm for moisture stress tolerance is required by designing appropriate screening techniques. Germination under saline soils followed by seedling survival and establishment is very important for appropriate plant stand leading to higher economic yields. For the precise selection of parental lines under abiotic stress resistance breeding programme, the physiological, biochemical and morphological traits responsible for resistance, their relation with economic yield and the genetic diversity in these traits need to be determined (Sinclair et al. 2004).

The oil content in the released varieties is ranging from 28 to 30% which needs an increase of 5–8% in this crop. In addition to different conventional breeding methods, mutation breeding and genetic engineering can also be the options for developing the high oil safflower lines. Fatty acid profile of this oil crop also needs alteration for its best commercial value. Due to high proportion of linoleic acid (78%) in its oil, it is considered as a healthy oil as it reduces blood cholesterol but makes shelf life of this oil very short and less suitable for frying purpose for its use in food industry. Appropriate reduction in linoleic acid and increase in oleic acid will eliminate this problem and will maintain the tag of healthy oil of this crop. Another aspect of safflower oil quality is increasing the gamma tocopherol content, which is antioxidant in nature. Concerted efforts should be made to assay the vast collection of germplasm for tocopherol diversity for initiating the breeding programme for this component.

## 9 Niger

Niger (*Guizotia abyssinica* (L.f.) Cass., $2n=30$) is an *Asteraceae* family oil crop cultivated in Indian subcontinent and East African countries (Getinet and Sharma 1996). Its cultivation originated in the Ethiopian highlands and has spread to other parts of Ethiopia. Both Ethiopia and India are excellent sources of germplasm for varietal development. In 2002, the variety Early Bird Niger was developed and adapted to the United States by Glenn Page. Niger seeds contain about 40% edible oil with fatty acid composition of 75–80% linoleic acid, 7–8% palmitic and steric acids and 5–8% oleic acid (Dutta et al. 1994). The meal remaining after the oil extraction is free from any toxic substances but contains more crude fibre than most oilseed meal. Niger is a completely outcrossing species with self-incompatibility mechanism. Variability exists for morphological characters (Pradhan et al. 1995); however, these characters are not discrete and hence complicate the niger improvement programmes. Niger seed populations in Ethiopia and India are very heterogeneous, indicating the great potential for yield enhancement through breeding.

### *9.1 Objectives*

Breeding objectives for niger seed are to increase seed yield and oil content and reduce shattering. With the development of single-headed plant types in sunflower and safflower, it has been postulated that single-headed dwarf types with uniform maturity must be developed for yield enhancement in this crop too. An increase in oil content appears feasible because of existing genetic variability, which can be used in breeding research. As niger seed is self-incompatible, breeders in India and Ethiopia have adopted population improvement programmes such as mass selection and sibbing. Recently, a protocol for *Agrobacterium tumefaciens* mediated genetic modification was developed. This crop falls under minor oilseed crop in India and a lot of progress has been made after 1985. Fifteen improved varieties have been developed for general cultivation among the farmers. Well-known improved cultivars in India are Ootacamund, Deomali, Paiyur 1, IPG 76 and JNC 6.

## 10 Castor

Castor (*Ricinus communis* L., $2n = 20$) an *Euphorbiaceae* family plant is an important non-edible oil crop of the arid and semi-arid regions of the world. India, Brazil, China, Russia and Thailand are the major castor growing countries of the world. Castor is grown on about 1.26 mha area with about 1.14 mt production and world average productivity is about 0.90 t/ha. India's share in total castor area and production is 59.1 and 64%, respectively, with 1.5 t/ha average productivity which is much higher than the world average productivity. Castor seeds contain 40–55% oil, the highest among all cultivated oil crops. The kernels contain 64–71% oil. Its oil is world's most useful and economically important natural oil. Its oil contains 84–90% ricinoleic acid of total fatty acids which makes it as a unique vegetable oil. Castor oil is highly stable and variation in fatty acid is very minimal making it the best raw industrial oil. Castor cake is a very useful organic manure which contains 6.0% N, 2.5% $P_2O_5$ and 1.25% $K_2O$. It is a rich source of protein (25–40%), sugar (25%) and minerals (10%). But the presence of toxic constituents like ricin/*Ricinus communis* agglutin (RCA) makes it non-edible. There is a real breakthrough in the varietal improvement of this crop which is evident from the transformation of perennial types to annual types. A large number of high yielding hybrids and varieties have been developed. Although castor is a monoecious plant, the proportion of male and female flowers is greatly influenced by both genetic and non-genetic factors (temperature, humidity, plant age, nutritional factors, etc.). Identification of completely pistillate plants and presence of exploitable levels of heterosis paved the way for development of castor hybrids resulting in quantum jump in productivity of this crop (Shifriss 1961; Moshkin 1967; Zimmerman and Smith 1966). Some of the objectives which need interventions are as follows.

### *10.1 Objectives*

Although good breakthrough has been made in the varietal development of this crop yet there is need to develop short duration varieties/hybrids suitable for specific situations like rainfed areas, semi-winter conditions, intercropping, mechanical harvesting, saline conditions and poor management conditions. Pistillate lines being used for hybrid development are highly sensitive to environment giving large number of ISF under high temperature and water/nutritional stress and reversion in any order in S type. Therefore, breeding programme on development and diversification of stable and superior combining pistillate lines with disease resistance needs acceleration. Under these circumstances, there is an urgent need to develop CMS lines which is not yet achieved because castor is mono generic and no wild species exist. Due to long duration and monoculture this crop is exposed to many insect pests (semi looper, castor capsule borer, jassids, white fly and thrips) and diseases (*Fusarium*, *Macrophomina* root rot, reniform nematode and *Botrytis* grey rot) which causes 30–40% of yield losses. Drought under rainfed areas and salinity in major castor cultivation areas are the abiotic stresses which limit castor production. Concerted breeding efforts are required to incorporate the resistance/tolerance against these biotic and abiotic stresses. Hybrids and varieties with medium to bold light coloured seeds with high oil content (>50%) and high ricinoleic acid (>90%) are the millers' choice, hence efforts on breeding such genotypes should be concentrated. Ricin and RCA are two highly toxic endosperm proteins present in the deoiled castor cake which makes its cake unsuitable for animal and human consumption as a protein supplement. Utilizing the enormous variability available for protein content, breeding efforts are required to address these problems to make this crop more competitive and remunerative. Biotechnological approaches like efforts towards development of transgenics for insect resistance (Sujatha and Sailaja 2007) and silencing ricin and RCA genes are likely to deliver good returns in the times to come.

## 11 Varietal Improvement in India

Indian subcontinent is the natural repository of the oilseed crops, yet is importing about 40% of the total edible oil in the country. Its vegetable oil imports further raise by 14% and a sum of Rs. 32,000 crore was spent on this import during the oil year 2009–2010. This makes India the world's largest oil importer. Oilseed crops research in India got a boost in 1967, when the Indian Council of Agricultural Research sanctioned a multi-disciplinary and multi-location "All India Coordinated Research Project on Oilseeds" including five crops, namely, groundnut, rapeseed mustard, sesame, linseed and castor and subsequently niger, safflower and sunflower were also included under this project. To focus research on individual crops, Government of India started separate National Research Centres and AICRPs on groundnut, rapeseed mustard, soybean and linseed and elevated these centres later to directorates. This has led to the development of good number of improved varieties in these crops and their production and protection technologies. In the mean time, Government of India has launched the Technology Mission on Oilseeds and Pulses (TMOP) in 1986, which took a number of innovative and integrated measures to harness the best production, processing and marketing technologies. After the implementation of TMOP, area under oilseed crops increased from 19.0 to 26.1 mha, production from 10.83 to 24.94 mt and productivity from 0.57 to 0.955 t/ha between 1985–1986 and 2009–2010 (Table 2.1).

**Table 2.1** Oilseed production (million tons) in India during 2001–2002 to 2009–2010

| Crops | 1985–2086 | 2001–2002 | 2002–2003 | 2003–2004 | 2004–2005 | 2005–2006 | 2006–2007 | 2007–2008 | 2008–2009 | 2009–2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Groundnut | 5.10 | 7.0 | 4.1 | 8.1 | 6.8 | 8.0 | 4.9 | 9.2 | 7.2 | 5.51 |
| Rapeseed mustard | 2.68 | 5.1 | 3.9 | 6.3 | 7.6 | 8.1 | 6.7 | 5.8 | 7.2 | 6.41 |
| Soybean | 1.02 | 5.6 | 4.6 | 7.8 | 6.9 | 8.3 | 8.7 | 9.4 | 9.1 | 10.05 |
| Other six | 2.03 | 3.0 | 2.2 | 3.0 | 3.1 | 3.5 | 2.9 | 5.4 | 4.2 | 2.97 |
| Total | 10.83 | 20.7 | 14.8 | 25.2 | 24.4 | 27.9 | 23.2 | 29.8 | 27.7 | 24.94 |

**Table 2.2** Crop wise varieties developed in eight oilseed crops in India

| Name of the crop | No. of varieties | | |
|---|---|---|---|
| | Before TMOP | After TMOP | Total |
| Soybean | 20 | 65 | 85 |
| Groundnut | 42 | 115 | 157 |
| Rapeseed mustard | 29 | 108 | 137 |
| Sunflower | 7 | 42 | 49 |
| Sesame | 28 | 48 | 76 |
| Linseed | 21 | 29 | 50 |
| Safflower | 9 | 20 | 29 |
| Niger | 1 | 15 | 16 |
| Castor | 16 | 19 | 35 |

There is tremendous increase in productivity of these crops but it is still lower than the world's average. Furthermore, stability of production is always a cause of worry in India.

The impact of technology mission on oilseeds and pulses is visualized with the development of a large number of area specific high yielding varieties of all edible oilseed crops (Shanmugham and Gunasekaran 2003, 2008) (Table 2.2). As far as improved technology is concerned, we have the improved varieties with very high yield potential in all the crops. From the comparison of present yield levels, and area and production with that of pre-TMOP period, very clear picture comes out and shows that we have attained much success to reach to the self-sufficiency, but still a lot has to be achieved. The crop wise achievements in terms of varietal development are given later.

## *11.1 Soybean*

Twenty varieties were released from 1969 to 1985, whereas 65 new high yielding varieties have been recommended for general cultivation by the farmers in a period of about 25 years, i.e. 1986–1987. The impact of these varieties can be observed by consistent increase in area, production and productivity of this crop. The most popular varieties of this crop are JS 335, JS 93 05 and MAUS 71 covering more than 85% area and are contributed significantly in the better production of this crop. Some new varieties are also covering the area gradually which will also help in increasing the production of this crop in the times to come.

## *11.2 Rapeseed Mustard*

This group of crop is a very complex one with four species, namely, *B. juncea, B. napus, B. rapa* (cvs toria, yellow sarson, brown sarson) and *B. carinata* grown for edible oils in India. The major area is under *B. juncea* and it contributes more than

85% of the total rapeseed mustard production. There are more than 137 varieties released for all the four oliferous species of *Brassica*. Presently, there are varieties with 2.5 t/ha of yield potential. In addition to varieties, hybrid development programme in *B. juncea* is also very strong and three hybrids have already been released for general cultivation. The dominating varieties of Indian mustard are Pusa Bold, Pusa Jai Kisan, Varuna, RH 30, Laxmi, Maya, Kanti, Rohini and Benoy (B 9) of *B. rapa* cv. Yellow sarson.

## *11.3 Groundnut*

Groundnut is also one of the three most important oilseed crops in India. A total of 157 varieties have been developed since 1969 of which 42 varieties were developed up to 1985 and 86 improved varieties have been released for general cultivation since 1986–2007 in this crop. The highest production has gone up to 8.1 mt during 2003–2004 but again due to weather vulnerability, the production has drastically come down to 4.9 mt during 2006–2007. There are very high yielding varieties in this crop and the major contributor in the production of this crop is varieties like M 335, TAG 24, ICGS 76, TG 7A, AK 12 24, HNG 10, etc.

## *11.4 Sunflower*

Sunflower is also one of the important oilseed crops contributing towards the national oil pool. Although this crop is covering about 10% of the country's total area but it fits well in all cropping systems due to its photo and thermo-insensitivity. This crop is of late introduction in the country and the first variety was developed during 1978. Since then 49 varieties and hybrids have been developed and released for general cultivation by the various public and private sector organizations. This is the only crop which has more than 80% sunflower growing area under the hybrids. From a negligible area during 1980–1981, now this crop has shown its presence in the Indian oil economy. The widely grown high yielding hybrids in sunflower are KBSH 44, KBSH 1, Poineer 6460, Poineer 3322. The most popular stable variety Morden which was released in 1982 is still having about 20% area of sunflower under cultivation.

## *11.5 Sesame*

Although sesame is grown in almost all the states of the country but the major states where sesame cultivation is being done are Rajasthan, Gujarat, Madhya Pradesh, Orissa and Maharashtra. As breeding for high yielding varieties is concerned a lot of efforts have been made for genetic enhancement of yield in this crop and as a result about 76 varieties have been developed of which 48 were developed after the implementation of TMOP. The varieties with about 1.0 t/ha yield potential have been developed for rainfed conditions too.

### *11.6 Linseed*

Linseed is one of the minor oilseed crop grown in India. In this crop also a lot of breeding work has been done and 50 varieties have been developed. The seed yield potential of the improved varieties under irrigated conditions is 1.2–1.5 t/ha.

### *11.7 Safflower*

It is another minor oilseed crop. A lot of efforts have been made in genetic enhancement of seed yield and 29 improved varieties have been developed in safflower.

### *11.8 Niger*

This crop also falls under minor oilseed crop in India and a lot of progress has been made after 1985. Fifteen improved varieties have been developed for general cultivation.

### *11.9 Castor*

India has made a big breakthrough in castor breeding programme. The first castor hybrid GCH 3 based on an exotic pistillate line was released for general cultivation in 1968. It is non-edible oil crop where 35 varieties and hybrids have been developed and are contributing in making India a global leader in castor production.

## 12 Research Needs for Yield Improvement and Its Stabilization

*Development of varieties resistant to biotic stresses*: In all the nine oilseed field crops grown in the country, the biotic stresses like insect pests and diseases effect the crops adversely in one or the other years due to which the production and productivity fluctuates to unexpected levels. In almost all the crops, barring few area specific examples, the insect pests and diseases cause havoc to these crops in the lack of resistant/tolerant varieties. Hence efforts are needed to develop such varieties for yield enhancement as well as stabilizing the production of these crops. Use of modern biotechnological tools will definitely help in development of varieties for biotic and abiotic stresses.

*Drought tolerant varieties with enhanced water use efficiency*: Water stress at various stages of crop growth in all the edible oilseed crops is another major limiting factor for realizing the potential yield of present day varieties. Specific efforts are required to breed the varieties having high degree of tolerance to moisture stress along with high water use efficiency to utilize the available moisture in under field conditions to minimize the losses to the crop.

*Development of varieties resistant to other abiotic stresses*: Other than water stress other abiotic stresses are frost in mustard, salinity in almost all oilseed crops, high temperatures at the time of sowing and maturity in the rabi oilseeds like rapeseed mustard and linseed. Efforts are needed to overcome these stresses by tailoring genotypes tolerant to these stresses in respective crops.

*Development of hybrids*: For breaking the yield ceiling, exploration of various possibilities which can help in increasing the yield potential of the different oilseed crops is required. It is realized that the improvement through the use of conventional breeding approaches is tending to level off, since these breeding approaches do not mobilize sufficient amount of genetic variation, whereas hybrids offer an opportunity for mobilizing greater amount of genetic variability and available high heterotic response in different crops. In order to increase the yield potential of soybean, *Brassica*, safflower, sesame, linseed and niger hybrid development programme needs to be intensified. With the encouraging results of hybrids in sunflower, a special network programme may be launched for development of hybrids in oilseed crops like rapeseed mustard, soybean, niger, safflower, sesame and linseed.

*Improvement of quality of oil and seed meal*: Specifically in rapeseed mustard, the emphasis should be made to develop double zero varieties (erucic acid <2% and glucosinolate <30 μmoles/g of defatted seed meal cake). For improving the keeping quality of soybean oil, efforts should be made to reduce the linoleic acid content. In the crops like *Sesamum* and linseed, also improvement in quality may be taken at priority for value addition to their oil. Ricin and RCA are the two toxic proteins present in castor deoiled cake which also need genetic interventions.

*Development of varieties with improved water use efficiency*: Water is the most precious natural resource in the times to come. Oilseeds are already grown on marginal lands with limited irrigation facility. Therefore, efforts are needed to develop oil crop varieties with high water use efficiency.

*Development of varieties with improved nutrient use efficiency*: The agronomical experiments show that the nitrogen requirement of almost all the oilseed crops is 60–80 kg/ha. The analysis of soils and plant samples shows a gap between nitrogen utilized by the plant and its availability in the soil. The higher dozes, i.e. more than 80 kg/ha of nitrogen does not yield good results. Hence, there is an urgent need to develop varieties which have high nutrient use efficiency.

## 13 Use of Molecular Tools for Oil Crop Improvement

For improvement of some of the biotic and abiotic stresses, there is problem either due to complex genetic control of that trait or non-availability of resistant source or non-availability of screening techniques or environmental effect on the traits under improvement. In such conditions, the possibility of using molecular tools like MAS helps in improvement of a trait. These techniques will not only help in the transfer of desirable trait but it will reduce the time taken for introgression of a particular trait. Where no source of resistance is available in the germplasm of particular crop, the transgenic approach may be explored for introgression of the resistance from other species.

Conventional methods of improving crops use the genetic variation available within the crossable limits. The germplasm provides the required parental lines for recombination breeding and making heterotic hybrids. Selection of right kind of parental genotypes, therefore, is the key to the success of a breeding programme. Those involved in genetic enhancement of crops heavily depend on the available passport data or results of limited evaluation of a sub-set of germplasm. A majority of the germplasm, although constitute the primary gene pool remain unutilized. Once the parental lines are chosen, they are inter-mated to generate segregating populations from which the desirable recombinants carrying the required gene combinations are selected. This process of selection is mainly based on phenotype in conventional schemes. Skilful eyes of the conventional breeder therefore play a vital role in selecting the desirable types from the pool of mostly undesirable segregants. Phenotype, however, is the product of interaction of genotype and environment. Particularly in respect to complex quantitative traits such as seed and oil yield, disease resistance, drought tolerance, etc., phenotype may not always reflect the actual genetic worth of the genotype. Even in case of Mendelian traits, selection of desirable segregants requires creation of selection environments, which may not be possible for routine screening of large populations. In contrast, selection based directly on genotype itself is more precise and efficient. Use of molecular markers to identify desirable recombinants, which is commonly known as MAS, makes gains from selection more predictive. The resources available in different oilseed crops with emphasis on the recent developments for carrying out marker-assisted breeding highlight the successful use of markers in selection and provide the prospect of MAS in oilseed improvement is summarized (Table 2.3).

A good progress has been made in soybean, *Brassica* and groundnut in development of molecular markers and genome maps, mapping and tagging QTLs and their application in MAS. The other oil crops need further biotechnological interventions for improvement of some of the specific traits which has been summarized as strength, weakness, opportunity and thrust for these crops (Table 2.4).

**Table 2.3** Molecular tools for oil crop improvement

| Crop | Marker/ trait | References |
|---|---|---|
| *Development of molecular markers and genome maps in oilseed crops* | | |
| Soybean | RFLP | Lark et al. (1993); Skorupska et al. (1993); Shoemaker and Specht (1995); Lorenzen et al. (1995); Xia et al. (2007) |
| | AFLP | Kiem et al. (1997); Xia et al. (2007) |
| | SSR | Cregan et al. (1999); Song et al. (2004); Xia et al. (2007) |
| | SNP | Yoon et al. (2007); Hyten et al. (2008) |
| *Brassica* spp. | RFLP | Figdore et al. (1988) |
| | Isozyme markers | Arus and Orton (1983); Chen et al. (1989) |
| | EST Mining | Bhati et al. (2010) |
| *B. oleracea* | RFLP and RAPD | Slocum et al. (1990); Kianian and Quiros (1992); Landry et al. (1992); Kearsay et al. (1996); Ramsay et al. (1996); Voorrips et al. (1997); Li and Quiros (2001); Saal et al. (2001); Gao et al. (2007) |
| *B. rapa* | RFLP and RAPD | Song et al. (1991) Chyi et al. (1992); Kole et al. (1997) |
| | SSR, IP | Li et al. (2010a) |
| *B. nigra* | RFLP and RAPD | Truco and Quiros (1994); Lagercrantz and Lydiate (1995) |
| *B. napus* | RFLP and RAPD | Hoenecke and Chyi (1991); Landry et al. (1991); Ferreira et al. (1994); Uzunova et al. (1995); Foisset et al. (1996) |
| | SSR | Lydiate and Sharpe (2003) |
| | SRAP | Sun et al. (2007) |
| *B. juncea* | RFLP, AFLP, RAPD | Sharma et al. (1994); Cheung et al. (1997); Axelson et al. (2000); Mohapatra et al. (2002); Sharma et al. (2002); Pradhan et al. (2003); Mahmood et al. (2005), Kalita et al. (2007) |
| | SSR | Koundal et al. (2008); Parida et al. (2010); Yadava et al. (2009); Pradhan et al. (2011) |
| | IP | Panjabi et al. (2008) |
| Groundnut | RAPD | Halward et al. (1992); Garcia et al. (1995) |
| | RFLP | Halward et al. (1991); Kochert et al. (1991); Paik-Ro et al. (1992); Halward et al. (1993) |
| | SSR | Cuc et al. (2008); Jayashree et al. (2005); Moretzsohn et al. (2005); Wang et al. (2007); Varshney et al. (2009) |
| | EST | Luo et al. (2005) |
| *Sunflower* | RFLP | Gentzbittel et al. (1994); Berry et al. (1995); Jan et al. (1998) |
| | AFLP | Gentzbittel et al. (1995); Langer et al. (2003); Tamborindeguy et al. (2004) |
| | SSR | Paniego et al. (2002); Yu et al. (2003); Tang et al. (2002); Heesacker et al. (2008) |
| | SNP | Kolkman et al. (2007); Fusari et al. (2008) |

(continued)

**Table 2.3** (continued)

| Crop | Marker/ trait | References |
|---|---|---|
| *Sesamum* | RAPD | Bhat et al. (1999); Davila et al. (2003) |
| | SSR | Dixit et al. (2005) |
| | AFLP | Laurentin and Karlovasky (2006); Laurentin and Karlovsky (2007) |
| | RAPD and ISSR | Sharma et al. (2009) |
| Linseed | Isozymes, RAPD, AFLP, RFLP | Spielmeyer et al. (1998); Oh et al. (2000); Fu et al. (2002), 2003; Krulickova et al. (2002); Adugna et al. (2006); Diederichsen and Fu (2006); Roose et al. (2006); Diederichsen (2007) |
| Safflower | RAPD | Amiri et al. (2001) |
| | AFLP | Johnson et al. (2007) |
| | RAPD, ISSR, AFLP | Sehgal and Raina (2005) |
| | ISSR | Yang et al. (2007) |
| *Mapping and tagging QTLs* | | |
| Soybean | *Phytophthora infestans* | Diers et al. (1991); Polzin et al. (1994) |
| | Corn earworm (*Helicoverpa zea* Boddie) | Rector et al. (1998); Li et al. (1998) |
| | Soybean aphid (*Aphis glycines*) | Rouf-Mian et al. (2008) |
| | Super-nodulation | Landau Ellis et al. (1991) |
| | Cyst nematode resistance | Concibido et al. (1994) Mudge et al. (1997); Schuster et al. (2001); Guo et al. (2005) |
| | Hard seededness | Kiem et al. (1990a) |
| | Seed shape traits | Salas et al. (2006) |
| | Sprout-related traits | Lee et al. (2001) |
| | Seed longevity | Singh et al. (2008) |
| | Height and maturity | Mansur et al. (1993a) |
| | Seed oil and protein content | Diers et al. (1992); Lark et al. (1994) |
| | Reproductive and morphological traits | Kiem et al. (1990b); Mansur et al. (1993b) |
| | Salt tolerance | Lee et al. (2004) |
| | Oil quality | Bachlava et al. (2008); Li et al. (2008) |
| *B. oleracea* | *Plasmodiophora brassicae* | Figdore et al. (1993); Voorrips et al. (1997) |
| | *Xanthomonas campestris* | Camarago et al. (1995) |
| *B. rapa* | Club root | Saito et al. (2006); Werner et al. (2008) |
| | *Xanthomonas campestris* | Soengas et al. (2007) |
| | *Albugo candida* | Kole et al. (1996) |
| | Fatty acids | Teutonico and Osborn (1994); Tanhuanpaa et al. (1996, 1998) |
| | Seed coat colour | Teutonico and Osborn (1994); Chen et al. (1997); Rahman et al. (2007) |
| *B. nigra* | Flowering time | Lagercrantz et al. (1996) |
| *B. napus* | *Leptosphaeria maculans* | Dion et al. (1995); Ferreira et al. (1995a); Leflon et al. (2007) |
| | Turnip mosaic virus | Walsh et al. (1999) |

(continued)

**Table 2.3** (continued)

| Crop | Marker/ trait | References |
|---|---|---|
| | *Sclerotinia sclerotiorum* | Zhao and Meng (2003) |
| | *Verticillium* wilt | Happstadius et al. (2003) |
| | *Albugo candida* | Ferreira et al. (1995c) |
| | Vernalization requirement | Ferreira et al. (1995b); Teutonico and Osborn (1995); Camarago and Osborn (1996) |
| | Oil content, protein, fatty acid | Arondel et al. (1992); Ecke et al. (1995); Hu et al. (1995); Tanhuanpaa et al. (1995); Jourden et al. (1996a, b); Jourden et al. (1996c); Thormann et al. (1996); Barret et al.(1998b); Fourmann et al. (1998); Hu et al. (1999); Schierholt et al. (2000); Zhao et al. (2006); Delourme et al. (2006); Qiu et al. (2006); Rahman et al. (2008); Nath and Goswami (2009) |
| | Glucosinolates | Uzunova et al. (1995); Toroser et al. (1995); De Quiroz and Mithen (1996); Hasan et al. (2008) |
| | Seed coat colour | Van Deynze et al. (1995) |
| | Male sterility/fertility restorer genes | Delourme et al. (1994); Jean et al. (1997); Delourme et al. (1998); Yi et al. (2006); Huang et al. (2007); He et al. (2008) |
| | Yield | Shi et al. (2009) |
| *B. juncea* | *Albugo candida* | Cheung et al. (1998); Prabhu et al. (1998); Mukherjee et al. (2001); Varshney et al. (2004); Panjabi et al. (2010) |
| | Seed coat colour | Upadhyay et al. (1996); Negi et al. (2000); Li et al. (2010b) |
| | Oil content | Sharma et al. (1999); Sharma et al. (2002) |
| | Erucic acid | Gupta et al. (2004) |
| | Glucosinolates | Stringam and Thiagarajah (1995); Good et al., (2003); Mahmood et al. (2003); Ripley and Roslinsky (2005); Ramchiary et al. (2007); Bisht et al. (2009) |
| | *Moricandia arvensis* | Ashutosh et al. (2007) |
| Groundnut | Nematode resistance | Garcia et al. (1995) |
| | Aphid resistance | Herselman et al. (2004) |
| | Rust resistance | Varma et al. (2005); Mondal et al. (2007) |
| | Drought tolerance | Varshney et al. (2009) |
| Sunflower | Fertility restoration and nuclear male sterility | Gentzbittel et al. (1995); Kusterer et al. (2002); Perez et al. (2005); Chen et al. (2006); Feng and Jan (2008) |
| | Branching | Gentzbittel et al. (1995); Rojas-Barros et al. (2008) |
| | Downy mildew | Mouzeyar et al. (1995); Slabaugh et al. (2003); Brahm et al. (2000) |
| | Orobanche | Tang et al. (2002) |
| | Rust (*Puccinia helianthi*) | Lawson et al. (1998) |
| | Chlorotic mottle virus | Lenardon et al. (2005) |
| | Oil quantity and quality | Perez et al. (2004) |

(continued)

**Table 2.3** (continued)

| Crop | Marker/ trait | References |
|---|---|---|
| | High stearic acid content | Perez et al. (2006) |
| | *Tph1* gene controlling beta - tocopherol accumulation | Vera-Ruiz et al. (2006) |
| | Pollen sterility and morphological traits | Kim and Rieseberg (1999) |
| | Restoring pollen fertility | Horn et al. (2002) |
| | Seed morphological traits | Yue et al. (2008b) |
| | Flowering | Leon et al. (2000) |
| | Lemon ray flower colour | Yue et al. (2008a) |
| | In vitro regeneration efficiency | Berrios et al. (2000) |
| | Drought tolerance | Jamaux et al. (1997); Herve et al. (2001); Kiani et al. (2007) |
| | Chlorophyll deficiency | Yue et al. (2009) |
| | Nutrient uptake | Lexer et al. (2003) |
| *Sesamum* | Closed capsule | Uzun et al. (2003) |
| Linseed | Flax rust (*Melampsora lini*) | Chen et al. (2001) |
| | Fibre quality | Roach and Deyholos (2007, 2008) |
| *Marker assisted selection (MAS)* | | |
| Soybean | Corn earworm resistance in soybean | Walker et al. (2002) |
| | Pyramiding of soybean mosaic virus resistance genes | Saghai-maroof et al. (2008) |
| Sunflower | Identification of maintainer | Yue et al. (2007) |

**Table 2.4** SWOT analysis of some oil crops

| Crop | Strength | Weakness | Opportunity | Thrust |
|---|---|---|---|---|
| Sunflower | Saturated maps, international, characterized gene pool | Still MAS not much adopted for QTLs | MAS could be adopted for several traits | *Alternaria*, yield plateau |
| Safflower | Skeletal map, markers (recently) germplasm | Very small group working on markers | Saturated maps, use of MAS, germplasm | *Alternaria* wilt |
| Sesame | Germplasm genomic resources | No map, very small group working on markers | Saturated maps, use of MAS, germplasm | Capsule shattering |
| Linseed | Germplasm genomic resources | No map, small group | MAPS and MAS | Bud fly |

## 14 Future Prospects of Marker-Assisted Selection in Improvement of Oilseed Crops

Since last 25 years after the publication of the first paper in 1986 on the development and use of RFLP markers for construction of linkage maps in tomato and maize, considerable progress has been made in the application of molecular techniques in oil crops. Now the focus has shifted to the use of sequence-based STS and SSR markers to generate very high density genome maps and tag gene/QTLs in *Brassica*, soybean, sunflower and groundnut. In some of the oilseed crops, SNPs are also being discovered and used to understand genetic diversity pattern. The first requirement for successful use of markers in breeding has been fulfilled at least for some of the traits with the availability of tightly linked markers. Besides, MAS with the use of other molecular markers has been demonstrated for both qualitative and quantitative traits.

Use of the markers was limited by the factors like recombination between the marker and the target gene, low level of polymorphism between parents with contrasting traits and lower resolution of QTLs due to interaction with the environment. With the recent developments in the design of genome-wide sequence based SSR and SNP markers, it would not be difficult to find solutions to these problems particularly in crops like soybean, sunflower, *Brassica* and in the near future in groundnut. Availability of high-density genetic and physical maps will enable finding markers physically closer to the target gene that would not allow failure of MAS due to genetic recombination in these crops. Development of allele-specific markers, markers based on the sequences of the genes, polymorphic SNP markers would eliminate the possibilities of breakdown of the marker-trait linkage, low level of polymorphism in narrow crosses, etc. Construction of high density genome maps using SSR markers is the desirable, which would allow map-based characterization of genomes and rapid tagging of useful genes.

With the available tightly linked markers as in case of nematode and virus resistance in soybean, MAS for qualitative traits seems immediately feasible. Pyramiding of a number of genes against different races of a particular pathogen and also against different pathogens, nematodes and insects should now be aimed at, which would allow sustaining the gains in productivity of the oilseed crops. Enhancing productivity further and stabilizing production particularly under abiotic stresses would require strategic use of markers in these crops. Many QTLs for seed and oil yield as well as for salt and drought tolerance in crops like soybean, sunflower and *Brassica* have been mapped. There is a need to validate and fine map these QTLs to identify tightly linked markers. Detection of QTL and its validation has to be carried out using a large population (>200 individuals) across several locations. Their expression needs to be confirmed in the target/new genetic backgrounds. More than one population may be used in parallel to understand the effect of different genetic backgrounds. It would be essential to understand the kind and the extent of epistatic interactions to identify desirable QTL combinations to be used in different situations. All these demand greater amount of research efforts, liberal funding, creation of additional infrastructure for precise phenotyping and high throughput genotyping, and newer experimental strategies.

The potential application of MAS in genetic improvement of the oilseed crops is quite high. More efforts are required in the coming years for realization of potential of MAS under field conditions in the form of commercial release of new varieties. Optimization of the cost of genotyping is required for routinely handling large samples as demanded by plant breeding experiments. Fortunately, due to significant reduction in cost, the genotyping technology is developing very fast, however, the investment in designing robust sequence based validated markers for important traits in oilseed crops should be viewed in the context of advantages in terms of saving time, effort and cost in the long run. While pursuing MAS particularly for difficult-to-phenotype traits, it should be kept in mind that use of markers is no substitute for conventional breeding. Conscious and strategic integration of MAS with traditional breeding of oilseed crops is desirable to harvest the benefits it offers.

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