10 Development of Vegetable Hybrids for Climate Change Scenarios

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Abstract

Vegetables are grown in diverse climatic conditions from temperate regions to extreme tropics. In tropics and subtropics, the climate shifts are more prominent, and major vegetables are grown round the year in these areas. Breeding vegetable crops suitable for different agroclimatic conditions is the key objective of the commercial companies. Many hybrids are already released by private companies which are adaptable under different agroclimatic conditions. Different breeding options are discussed to meet the challenges of climate change.

More than 100 genera are grown globally as fresh vegetables, but 35–40 genera are the important vegetables which are grown in major vegetable growing areas of the world. Presently, global vegetable seed business is worth US$ 8.0 billion out of US$ 42 billion total seed industry (Fig 10.1). In the last 40 years, it has grown significantly from US$ 0.8 billion to US$8.0 billion, by almost 10 times (Fig 10.2). This clearly indicates the importance of vegetables in food, health and nutrition globally. The Asian vegetable industry is also growing, and traded seed market of vegetable seed is touching $3 billion, and China is the largest partner with $1.5 billion (excluding potato and garlic) (Fig 10.3). The ever expanding area as depicted by the seed sales is indicating that the new varieties are significantly contributing towards higher productivity and value addition thru taste, flavour and higher shelf life.

10.1 Introduction

Globally, tomato is the biggest crop and occupies 11% of the total vegetable seed market. The crops like cabbage, sweet pepper and lettuce occupy about 7% each of the market. The watermelons, onions, melons, Chinese cabbage and hot peppers occupy around 5% of the total vegetable seed market (Fig. 10.4). As the second

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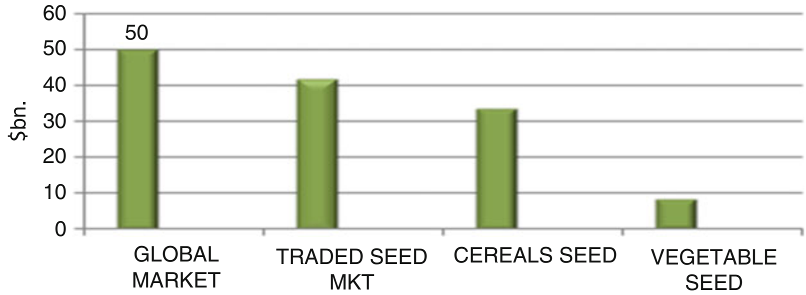

Fig. 10.1 Global seed market and seed market of crops

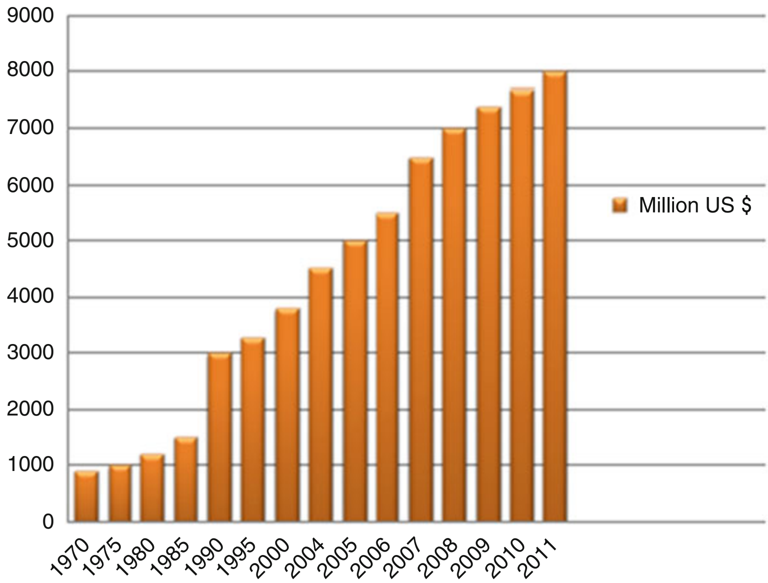

Fig. 10.2 Growth of vegetable industry in last four decade

largest producer of fruit and vegetable in the world after China, India produces a wide variety of vegetables. As per the National Horticulture Board information of 2010 published by National Horticulture Board, India produced 71.50 million ton of fruits and 134 million ton of vegetables during 2009–2010. The area under cultivation of fruits stood at 6.4 million ha, while vegetables were cultivated at 8.0 million ha (www.apeda.gov.in).

India is the largest producer of ginger and okra amongst vegetables and ranks second in production of potatoes (10%), onions, cauliflowers, eggplant, cabbages, etc. The vast production base of fresh vegetables offers India tremendous opportunities for export. During 2010–2011, India exported fresh fruits and vegetables worth Rs. 38.56 billion which comprised of fruits worth Rs. 26.35 billion and vegetables worth Rs. 12.21 billion. Mangoes, walnuts, grapes, bananas and pomegranates account for larger portion of fruits exported from the country, while onions, okra, bitter gourd, green chillies, mushrooms and potatoes contribute largely to the vegetable export basket. The major destinations for Indian fruits and vegetables are Bangladesh, UAE, Malaysia, Sri Lanka, UK, Nepal, Saudi Arabia, Pakistan and Indonesia (www.apeda.gov.in).

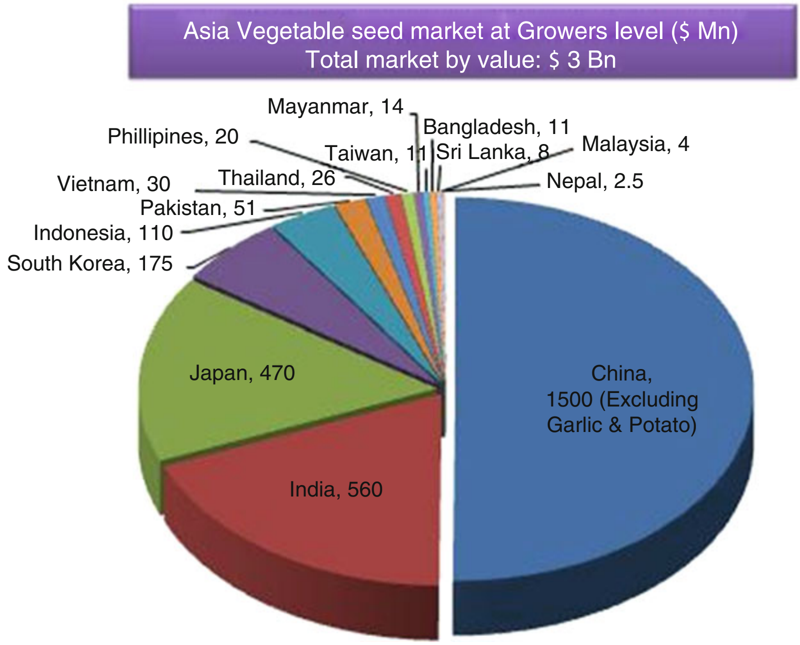

Fig. 10.3 Vegetable seed market of Asia

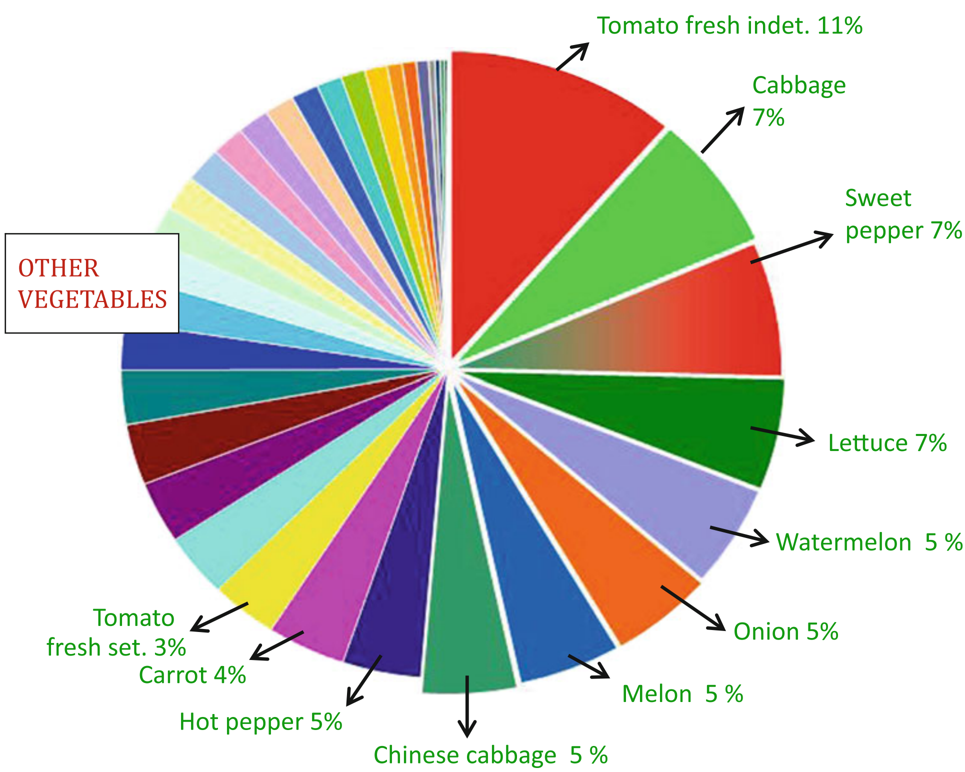

Fig. 10.4 Crop wise segmentation of vegetable crops

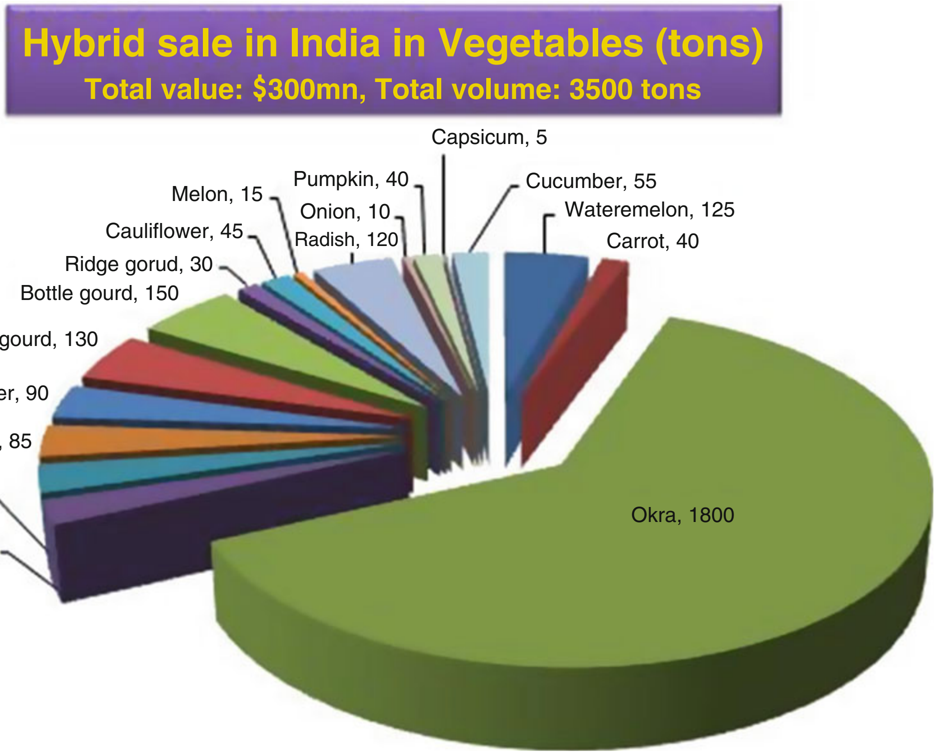

Fig. 10.5 Hybrid vegetable seed sale in India

Total traded seed industry in India is worth US$ 2.3 billion, out of which vegetable accounts for US$ 560 million. Varieties of vegetable crops are grown in India based on the local tastes and recipes. At present, about $260mn of the value of seed come from open pollinated varieties particularly bulk crops like peas, beans, coriander and radish. and $300mn comes from hybrids. In hybrids, by value, tomato, hot peppers and okra have 18% market share each, while cabbage, cucumber and watermelons have 5–7% market share each. Total hybrid seed market is more than $300 million, and more than 3,500 Mt seed is being produced to have overall more than 50% seed replacement rate in hybrid vegetables (Fig. 10.5).

Open pollinated varieties (OPV) vegetable seeds are sold in big quantities in many crops. Still, OPVs of Okra, tomato and hot pepper are being sold in many markets because of local market needs and tastes required for local recipes. Presently, around 40,000 ton seeds of OPVs in around 25 vegetable crops are being sold with a total value of more than $ 260 million. Out of the total OPVs sold in India, 70% is made of beans, coriander, onion and peas by value. The private seed industry is continuously improving the OP varieties and introducing high-performing research varieties. Many of these varieties are also showing intermediary resistance to diseases. In vegetables, even in OPVs, the seed replacement rate is very high, and farmers buy fresh seed every season/year (Fig. 10.6).

10.2 Climate Change and Its Impacts

With the increasing population which is presently at 7.0 billion, the pressure on land is impacting the climate. The greenhouse gases

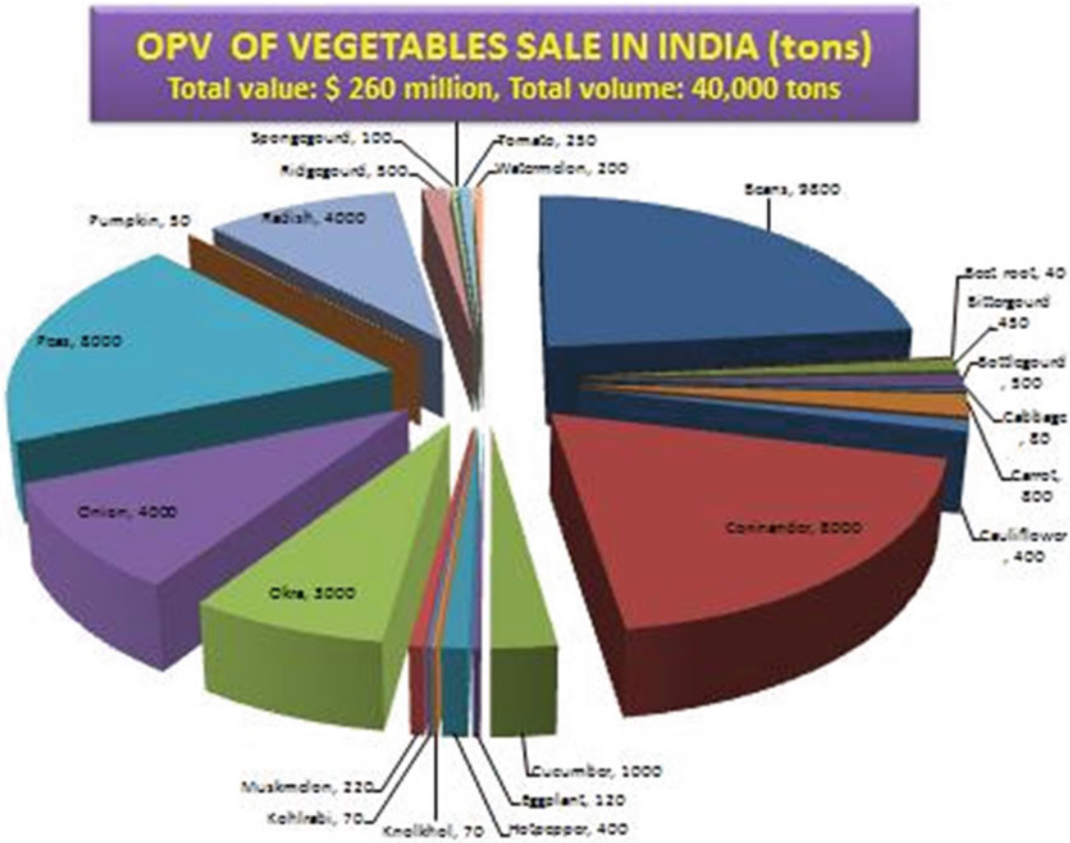

Fig. 10.6 Open pollinated vegetable varieties sale in India

emissions due to human activities are the biggest concern for the climatologists. The rise in temperature and other related changes like increase in sea level, more rains or drought will impact all the living things on the earth. Agriculture which is sensitive to the climate changes will react sharply to these changes. The cropping pattern change and the change in planting seasons will put pressure on the breeders to develop adaptable hybrids for these conditions. With the changing climatic conditions, the host pathogen interactions will also change. It was observed that more virulent pathotypes are emerging and affecting the crops. The continuous struggle of developing resistance in vegetable crops is a biggest challenge for breeders under these conditions.

10.3 Breeding for Abiotic Stresses

The abiotic stresses like temperature, drought, salinity and floods are the consequences of changing climatic conditions. The breeding for resistance to these stresses is going on presently in many crops. Crops like tomato and hot peppers are bred to grow under high and low temperature without losing the ability to yield as much as in the normal conditions. Similarly, now many drought genes have been identified and being inserted into these crops to develop proof of concept in conserving and utilising the available moisture. These products will help in providing yield stability in areas with limited water supply. Similarly, many tomato lines are under development which can tolerate high level of salinity.

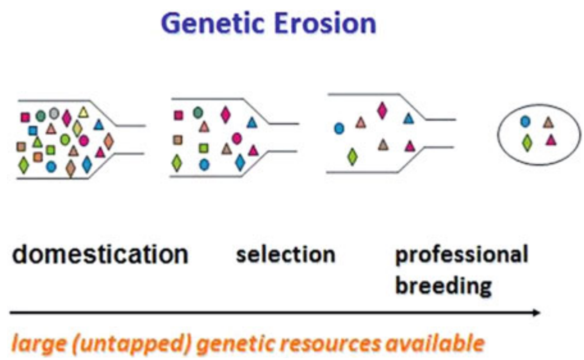

Fig. 10.7 Loss of important genes during domestication

Abiotic stresses are the complex traits and need further research before these can be commercially exploited.

10.4 Breeding for Disease Resistance Under Changing Climate

Most of the vegetables in tropics and subtropics are susceptible to many diseases. There are heavy losses of yield and quality due to disease infestation and chemical sprays. Heavy use of chemicals to control these diseases caused contamination of soil, water and atmosphere. These are also causing problems to human health and animals. Excessive use of chemicals have led to development of resistances in many pathogens. The acceptance of organic food is also pushing breeders to develop resistant varieties.

10.4.1 Losses due to Diseases Vegetables

Around 35–40% loss of vegetable production happened every year globally. There are about 100,000 microbial/fungal pathogens, 10,000 insect pathogens and 30,000 weeds causing extensive damage to vegetable crops. Worldwide, 20,000 pesticide formulations are being used to control pests, and out of which 1,600 are commonly used formulations. It is estimated that almost 3 million tons of chemicals is consumed in vegetable growing globally. In India, almost 1.40 lakh t of pesticides are consumed in vegetable growing. The pre-harvest losses in vegetables in India are 10.5% (Betne 2011).

10.4.2 Breeding Approaches for Disease Resistance

Various approaches have to be deployed to impart disease resistance to different vegetable crops. These include conventional approaches through wide hybridisation with high selection pressure. The use of MAS and MAB is going to be an efficient tool to breed for resistance development in elite material. The introgression of resistant genes, isolated from same or different species through genetic modification, is an important, specific and efficient tool. All these approaches are required to achieve the durable resistance to the developed and cultivated varieties. During domestication of these crop plants, we have lost many important genes which we have to recapture under existing selection pressure (Fig. 10.7).

10.4.2.1 Breeding for Multiple Resistance in Hybrids

Most of the vegetable crops are infested by multiple diseases including fungal, bacterial, viruses and insects. Most of the diseases are in epidemic form and multiple resistances have to be incorporated for the better performance of hybrids. Major crops like tomatoes and hot peppers are suffering from multiple diseases, and developing resistance

YIELD LOSSES DUE TO MAJOR VEGETABLE DISEASES IN INDIA

OKRA	YVMV	50%
TOMATO	TYLCV	30-40%
HOT PEPPER	VIRUS COMPLEX	40-50%
CABBAGE	DBM, BLACK ROT	50-70%
CAULIFLOWER	DBM, BLACK ROT	30-50%
EGGPLANT	FSB	40-60%
CUCUMBER	FUNGAL,VIRUSES	30%
ONION	FUNGAL	20-30%

Fig. 10.8 Yield losses due to diseases in vegetables

to all these diseases is a herculean task by using conventional breeding techniques. The yield losses are heavy due to these diseases.

Pre-harvest losses due to these diseases are significantly high (Fig. 10.8). In tomato and hot pepper, the losses due to viruses is as high as 50%, while diamond back moth (DBM) and black rot caused up to 70% losses in the crop at pre-harvest level.

10.4.2.2 Problem of Pesticide Resistance and Pesticide Residue

Worldwide, around 500 insect-pests, mites and spiders have developed pesticide resistance including 31 in India. Diamond back moth (DBM) has also developed resistance to many pesticides. Similarly, fruit and shoot borer of eggplant, many mites and thrips have developed resistance to available pesticides. The origin of new races in fungal diseases and new strains of bacteria is the other challenge with pesticides and breeding companies. The other issue is of pesticide residue. Since many vegetable crops are eaten raw as salads, these residues cause lot of health risks. Many organisations have evaluated the residue level from fresh vegetables, and more than 60% of the samples are showing residues above the permitted limits. All these issues are pointing towards the need of development of resistance through breeding, and only development of resistant varieties can solve some of these issues.

10.5 Sources of Resistance

Conventional breeding coupled with molecular marker assistance is the best choice for breeding for resistance. Many wild species are rich sources of resistance genes in many vegetable crops. For example, in tomato, the genes for TYLCV are derived from *L. pimpinillifolium* while insect resistance from *L. pennellii.* Drought resistance genes are found located in *L. chilense* and *L. pennellii.*

Similarly, bacterial wilt which is caused by *Ralstonia solanacearum* is a major disease in many parts of Asia. The resistance source is found in Hawaii 7,996 accession. For phylotype I strain which is predominantly found in Asia, large BW QTLs are detected on chromosome 12. Multiple BW QTLs are also located on chromosome 6 which are important for resistance to phylotype I and II strains.

It is important to build durable resistance through wide hybridisation and making selection by markers to achieve accumulation of genes for resistance.

Similarly in peppers, many wild relatives have important genes for resistance against fungi and viruses in species like *Capsicum chinense*, *C. baccatum* and *C. frutescens.* We have to reconstruct the genome using the crosses between the cultivated species and these resistant species and bring back certain important genes which we had lost during earlier selection pressure. The new tools of molecular markers and genome sequence will facilitate to create durable resistance against diseases developing under changing climatic conditions.

The host and pathogens are in dynamic equilibrium with each other, and both are evolving and changing under climate shifts. Pyramiding genes and alleles is a continuous process, and this will lead to a durable resistance to the released hybrids.

10.5.1 Marker-Assisted Breeding

The molecular marker tools which are available to the breeders have unprecedented power for selection of the right genotype. With the marking of certain genes within a plant genome, breeder can trace it throughout the plant life cycle. Breeder can determine the trait before the seed actually go to the ground. Now, the genome sequence is happening at a faster pace, and the available data allows breeders to significantly shrink the time line between initial discovery and the commercial introduction of the hybrids. Today, breeders can get the genetic analysis information from just a portion of the seed coat. DNA now is analysed in close to real time. With DNA analysis from the chip of the seed, a breeder can segregate the seed before sowing based on the presence and absence of a trait. This is going to increase the efficiency almost tenfolds, and breeder can bring the commercial products in 3 years rather than waiting for 8–10 years. With the hundreds of datapoints getting available, the breeders have huge information about the genetic constitution of the seed before planting a single seed in the soil. Many vegetable crops genome is sequenced like tomato, cucumber and melon, and a lot of valuable genes are tagged to be used in breeding and development of products. Presently, markers are being used for TYLCV, TSWV, Ph, Cf, Mi genes.

10.5.2 Gene Insertion Technologies

10.5.2.1 Insect-Resistant Traits

Today, insect-resistant cultivars developed by inserting gene from soil bacteria, the Bt gene, has revolutionised the agriculture. The significant reduction in pre-harvest losses due to the resistance and lesser use of pesticides helped the growers significantly. New genes for insect resistances are being identified with new modes of action. Bt genes are introduced in tomato, okra, eggplant, cauliflower and cabbages for the control of lepidopterans insects. The initial results are very encouraging, and vegetable growers are going to be benefitted by these technologies. The Bt eggplants which may be released soon have great advantage for the farmers against fruit and shoot borer, *Leucinodes orbonalis.* Similarly, *Helicoverpa* species which are infesting fruits of okra and tomato are controlled by Bt. insertions. The diamondback moth (DBM) which attacks cole crops particularly Brassicas have shown resistance too many pesticides. The durable resistance source in the germplasm is not available. The only alternative is to look for gene insertion from other species to impart resistance. Bt. genes were introduced in cauliflower and cabbages, and the initial field trials have shown excellent control of DBM and other lepidopterans insects like *Spodeptra*. Now, genes like Chitinase have been identified to control fungi in vegetable crops. For viruses, already coat protein (CP)-mediated resistance has been used in many crops like squash and papaya. The RNAi and miRNA technologies are being used to control particularly Tospoviruses. These technologies will impart durable resistance to these crops. Companies are continuously searching new genes with new modes of action and even new sources of insect toxins.

10.5.2.2 Herbicide-Tolerant Traits

Herbicide-tolerant trait played a significant role in many crops. Presently, 90% of soybeans and 70% of the corn are planted using the herbicide-tolerant trait. With this trait, no-till cultivation is possible which will not only solve the problem of soil structure alterations due to extensive ploughing but also protect the fauna and flora of soil. With the crop residue in the soils, the organic matter is improving, and the natural insect population increase also attracts and improves the bird population. With Monsanto and Dow AgroSciences coming out with new-generation herbicide-tolerant traits which will control broadleaf and grass weeds. Stacking multiple herbicidal genes will provide diversified options for weed control.

10.5.2.3 Nitrogen Use Efficiency Traits

Several seed companies are now developing traits that allow the crop plants to better utilise the available nitrogen. Fertiliser is the key and an expensive input. Lot of nitrogen gets percolated or washed away is not fully utilised by the plants. So any trait which can increase the efficiency of fertiliser uptake will help the growers to reduce the cost of crop production.

10.5.2.4 Yield Potential Traits

Starch biosynthesis plays an important role in plant metabolism. ADP-glucose pyrophosphorylase (ADPGPP) is a critical enzyme for regulating starch biosynthesis in plant tissues. Starch biosynthesis and dry matter accumulation were enhanced in potato tubers of plants transformed with glgC gene from *E. coli* encoding ADPGPP enzyme. The glgC gene has been introduced in rice also, and the yield potential of these lines is being evaluated. In tomato, florigen gene is identified for yield enhancement. A hybrid tomato plant that gives a bumper crop of sweeter tomatoes has been created by scientists, by cross-breeding from two parent plants.

The hybrid produces about 60% more tomatoes than the average tomato plant, and the sugar content of the fruit is also higher than normal. It carries a mutation in a single gene that controls the timing of flower formation.

The discovery could be applied to other valuable food crops such as potatoes, peppers and eggplant, the geneticists hope. The crop-boosting mutation is seen as a potentially valuable tool to increase global food production in the coming decades.

The scientists discovered the critical role of the florigen gene, which promotes flowering, by cross-breeding a collection of 5,000 tomato plants that had been deliberately mutated, each in a different gene. The researchers found that plants carrying one normal and one mutated florigen gene showed remarkable "hybrid vigour," with a significant boost in yield and sweetness.

10.5.2.5 Male Sterility System

The male sterility system which is being used in *Brassica napus* is a really valuable tool in improving the hybridisation in crops where male sterility systems are either not available or not stable or restoration of fertility is an issue. The barnase-barstar system is also being tried in other crops like vegetables to diversify the male sterility sources.

10.6 Future Technologies to Control Biotic Stresses

With the genomic sequences becoming available for many crops, the identification of function of many important genes and their regulation will provide extra tools in the hands of the breeder. Biotic stresses which are controlled by multi and recessive genes are difficult to breed. For this, we need technological interventions. The targeted mutations (TILLING) technology will also help in generating new gene pool with resistant genes. The evolving pathogens will continuously throw challenges for the breeders in the changing climatic conditions, and breeders have to evolve the host to counter the challenge, and this struggle will continue and provide sufficient work to the breeders.

References

Website of APEDA (www.apeda.gov.in)

Betne R (2011) Indian vegetables: nutrition pack with toxic cocktail. Toxic Link 1–7