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Review article

Breeding vegetables for protected cultivation: A review

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Abstract

Protected cultivation of vegetable crops was given a high priority and developed very rapidly during the past 15 years in India. Initially, vegetable cultivars commonly used for open field production were also started to grown under protected conditions. Despite various measures, many problems arose due to unfavorable ecological conditions in protected environments. Since the late 1980's and early 1990's, breeding of vegetable cultivars for protected conditions has been carried out by taking advantages of both conventional methods and biotechnological tools. One of the main research efforts include screening and evaluation of breeding materials for tolerance to various biotic and abiotic stresses. Another effort focused on the creation and development of new breeding materials (variety, cultivar or breeding line) for protected conditions by selection, introduction, crossing and biotechnological methods, including isolating from popular F_1 genotypes, wide crosses, tissue and cell culture, protoplast regeneration, gene transfer techniques, molecular marker assisted breeding and many other approaches. As most hydroponic cultivation and grafting tools are carried out inside the protected conditions, more cultivars adapted to this type of culture are also urgently needed.

Key words: Breeding, grafting, hydroponic, protected cultivation, vegetable.

Introduction

Agriculture has been the backbone of our Indian economy and till date approximately 43% of India's geographical area is being used for agricultural activity related to various perspectives (Anonymous 2018). Though after the independence of India, special emphasis on agriculture in the five-year plans and steady improvements in irrigation, technology, application of modern agricultural practices and provision of agricultural credit and subsidies since the Green Revolution have increased crop yields per unit area of all crops but today, fragmentation of land, small land holdings, urbanization, industrialization, declining biodiversity, climate change and food demand of burgeoning population are mounting a great pressure on the limited resources of the country (Kohli *et al.* 2010). Furthermore, when this thing was compared internationally, the average yield in India is only 30% to 50% of the highest average yield in the world. Thus, alternate means for improving the quality and increasing the productivity from limited land is a matter of concern for researchers and policy makers (Kacira 2011). Vegetable crops on the other hand, hold prime responsibility of meeting nutritional requirement of the population, generating employment and improving economic conditions of the people. During the last four decades, area and production of vegetables has increased by 77 and 187% respectively, but still per capita availability is lower than the recommended (300g) dietary requirement (FAO 2013). Therefore, it is extremely important to improve the productivity of vegetables by adopting intensive cultivation practices like protected cultivation to produce more produce per unit area with increased input use efficiency.

Protected cultivation offers an opportunity to grow vegetables under adverse conditions, in which natural environment is modified to achieve optimal growth and development of the plant. The modification of micro-climate around the plants by trapping the solar energy gives new dimension to

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produce more per unit of area (Wani *et al.* 2011). It has been estimated that if one lakh hectare area under vegetable cultivation is brought under poly house cultivation the annual availability of vegetables will be increased by at least 100 lakh tons. Besides this, it will also significantly increase the job opportunities for the skilled rural men, youths and rural women. Protected cultivation is not only used for off-season high value-low volume vegetable production, but also for nursery raising, hybrid seed production and breeding programmes (Castilla *et al.* 2004). It also enables vegetable growers to address the vagaries of climate, realize high returns per unit area and offer other benefits like earliness, longer duration, and efficient use of fertilizers and eco-friendly management of pests, weeds and diseases. In last 20 years, this technology has been adopted by farmers all over the country, resulting in increase in area from 525 to 40,000 ha.

This technology has a very good potential especially in urban and periurban areas adjoining to the major cities which is a fast growing market for fresh produce of the country. But it requires very careful planning, maintenance and management about timing of production and moreover, harvest time to coincide with the shortage period of availability of vegetables and high market prices, choice of varieties adopted to off season environments, and able to produce higher and economical yields of high quality produce etc. As per the requirement of geographic region, work on design of protected structures, crop selection and agronomic practices has been done, but little attention has been paid to develop exclusive varieties for enclosed, vertical and fixed space/structures to harness the maximum potential (Chandra *et al.* 2000).The greenhouse production system has climate regulation provisions and this system in India is known as protected cultivation (Singh and Bainsha 2015). Due to the poor sources of energy, India has to depend on various innovative methods to create the conducive climate for the growth and production of the plant system. Such engineered innovative methods are called as protected cultivation. Protected cultivation is a microclimate modification method surrounding the plant for best production potential. Moreover, the biotic and abiotic stresses during the crop production gets reduced (Singh and Peter 2014). Furthermore, the land and water requirements are minimized under the protected cultivation to yield early and more produce.

Vegetables are an integral part of our daily diet as they are rich sources of various health building substances. In the recent past there is tremendous shift in vegetable consumption in India. Even though the production of our country is much less than that of our requirement, we are still doing best in terms of production potential, standing second in the world. By the year 2050 it is estimated that the total requirement will rise to 350 million tones (FAO 2013). Therefore, to achieve this target we need a continuous production system throughout the year and off season production potential. Solution for this lies in protected cultivation system/greenhouse production system and the development of hybrids for the protected crops by using various breeding approaches. Breeding methods involved for the breeding of crops grown under the protected structures may be conventional and biotechnological (Singh 2012). The crops which give higher yield, better returns and where multiple harvests are possible are suitable for protected cultivation technology. Such crops belongs to the Solanaceae (tomato, capsicum,) and Cucurbitaceae (cucumber and gherkin) families. These crops accounting for greater than 80% of the protected area are suitable for greenhouse conditions. The other high value vegetables such as bitter gourd, muskmelon, long melon, cherry tomato, hot pepper and summer squash have demand around metropolis and big cities during winter or off-season, therefore their suitable varieties adapted to protected cultivation need to be developed to make protected cultivation a viable option (Singh 2012).

Development of protected vegetable production

Although India had a long history of protected vegetable production, only simpler forms of protection were employed to grow a few vegetables which were tolerant to low temperature during winters and early spring. As the plastic industry developed and various types of plastic films became available, different types of plastic films tunnel, including large, medium and small size, were developed. Since the mid 1980's a new lean to form of sunlight-heated plastic greenhouse has been used to produce the fruit vegetables without supplemental heating during the winter and spring (Baille 2001). This revolutionized the vegetable production under protected conditions which is considered as the most important form of vegetable production. Protected conditions are also used for hardening the seedlings to be transplanted in the open field. Before 1995, the area of cucumber and tomato production was much less for open field conditions i.e. less than 50%. But as the growing conditions improved and growers were encouraged by the consumers market, more and more vegetable crops are being grown successfully under protected conditions without heating, which was impossible earlier (FAO 2013). The ecological environment under protected conditions is quite different from that in the open field. In protected environment, humidity is higher, rotation is limited and diseases become more epidemic frequently. Heating protection is an important measure for management of protected environment during winter and early spring. Light intensity is low because of frequent cloudy weather and multi-layer coverage (Janick 1986). This causes a shortage of CO_2 and lower light intensity for normal photosynthesis. Thus, high resistance to diseases and tolerance to low temperatures and light intensity and a lower CO_2 compensative point are required for vegetable crops (Goncharova *et al.* 2004).

Meeting consumer preferences through vegetable breeding

Vegetable breeding satisfy the needs of both the consumer and the grower. The general objectives for growers are higher yield, disease and pest resistance, uniformity and abiotic stress resistance. Objectives for consumers are quality, appearance, shelf life, taste, and nutritional value. Quality in vegetable crops, in contrast to field crops, is often more important than yield. For growers to survive, cultivars must be accepted by the market. Thus, color, appearance, taste, and shape are usually more important than productivity (Allard 1960). For example, tomatoes to be used either fresh or in processing must have distinct quality characteristics. Fresh tomatoes must have acceptable flavor, color, texture, and other taste parameters to satisfy consumer demands and handling requirements. Processing tomatoes, on the other hand, must have intrinsic rheological characteristics that make them suitable for various processing applications, such as juice, ketchup, sauce production etc. Traditional breeding requires the selection of a tomato genotype or a related wild species that has a desirable trait, such as early ripening or disease resistance, and crossing it with another tomato cultivar that has a good genetic background. The desired result is an early ripening tomato or cultivars that are resistant to pathogen attack. In this way, several thousands of tomato cultivars have been developed over the years. The final goal of vegetable breeding programs is then to release new cultivars having elite combinations of several desirable horticultural characteristics (Mishra *et al.* 2010).

Other important objectives of vegetable breeding are disease and pest resistances. Since the early days of the 20th century, traditional breeding for disease resistance in vegetables has been a major method for controlling plant diseases. Cultivars that are resistant or tolerant to one or a few specific pathogens are already available for many vegetable crops whereas, multiple resistant hybrids are currently used in vegetable production. Pest resistance is essential in vegetable production but is marginal in vegetable breeding research. Resistance may be unstable due to genetic variants of the insect that are able to overcome that source of resistance (Orton *et al.* 1984). Depending on the complexity of the interaction between the pest and the vegetable plant, plant resistance may break down rapidly or be long-lived. Viruses can substantially reduce production and quality and are becoming increasingly problematic worldwide due to the absence of virus resistant germplasm for many important vegetable crops (Niu *et al.* 1984).

Selection and breeding for protected cultivation

During the early stages in the development of protected production of vegetable crops, cultivars for open field conditions were grown. Soon we found many of them did not grow well under protection. The protected crop industry required that cultivars have early maturity, high resistance to diseases, high tolerance of low temperature and low light conditions, low CO_2 compensative point, high quality and high yield. It was difficult for the field cultivars to meet all these conditions (Nuez 1986).Therefore, efforts have been focused on the selection and breeding of cultivars for protected environment. Some good materials were selected from the wild sources of germplasm and were screened for desirable characteristics. Some materials are resistant to more than one kind of diseases, while others demonstrate more than one excellent trait for commercial production. These materials play a very important role for breeding the new cultivars needed for protected growing conditions. The success and economic returns from protected cultivation depends upon the four major factors i.e. what to produce, when to produce, how to produce and where to sell. The cultivars should have uniform and indeterminate growth habit, more number of internodes at short distance, resistance to nematodes especially root knot nematode, sucking pests, resistance to soil pathogens, tolerance to low temperature, low light conditions, low CO_2 compensative point, longer harvest duration, high quality and higher yield. Normally in polyhouses/ green houses, fruit thinning is done for proper development of the cluster, and if variety possesses self pruning gene, labour can be saved. There is one aspect that those cultivars which are suitable for open field conditions are usually not suitable for the protected structures (Singh 2012). Variety should be developed according to the three major extrinsic factors i.e. the growers, traders and consumers. From farmer's point of view higher economic yield, extended harvest duration and resistance to biotic and abiotic stresses are the major considerations. The traders demands longer shelf life and unique characteristics of the produce, must be easy to use, versatile, good in taste and rich in nutritional properties is admitted by the consumer.

Various recent advancements in breeding technologies has therefore led to the development of new cultivars having resistance to various biotic and abiotic stresses. Nutritional quality and other specific traits such as parthenocarpy, indeterminate growth habit and suitability to grafting can also be achieved. The biotechnological approaches have facilitated the gene pyramiding of multiple traits in a single cultivar (Singh 2012). The recent developments on gene silencing or editing of the targeted gene can further trigger the targeted breeding programme on protected cultivation..

Breeding for tomato under protected conditions

Tomato is a premier and one of the most popular globally grown throughout the year. It belongs to the family Solanaceae and originated from Peru-Ecuador Bolivia region of the Andes in South America. It is recognized as an important commercial and dietary vegetable crop and occupies a prominent position among vegetables, due to its export value (Singh *et al.* 2014). One of the most important factors in the intensification of greenhouse tomato production is the introduction of new high-yielding varieties and hybrids, which have high resistance against diseases and pests adapted to new technologies and protected conditions (Balashov 2006; Gavrish 2015). The development of high yielding varieties requires detailed knowledge of the genetic variability present in the germplasm of the crop, the association among yield components, input requirements and culture practices (Meng *et al.* 1999). Plant breeders have produced high-yielding varieties, though little attention has been paid to the fruit quality (Foolad 2007). Rajasekar *et al.* (2013) also reported that growth, development, productivity and quality of any crop are heavily depending on the interaction between the plant genetics and the environmental conditions of plant growth. Kumar *et al.* (2015) evaluated tomato lines for quantitative traits such as plant height, fruit yield, fruit weight, total soluble solids, fruit weight loss and fruit shelf-life in greenhouse as well as plants which were grown in field conditions. They found that in greenhouse conditions, the plant height was between 93.3 to 165 cm. The total fruit yield per plant was between 615 to 1730 g, fruit weight was between 34.4 to 82.0 g. Number of locules per fruit was between 2.0 to 5.0. Therefore, the main aim of the protected cultivation is to achieve independence of climate and weather, also to allow crop production in areas where the natural environment limits or prohibits plant growth. Under protected environment, the natural environment is modified to the suitable conditions for optimum plant growth, which ultimately helps in the production of tomatoes with suitable quality for export and domestic consumption. Tomato crop grown under net house perform better and produce higher fruit yield than that grown in open field conditions. Tomato can be grown successfully in the off-season in net house for obtaining higher fruit yield. Occurrence of frost coupled with low temperature during the months of December and January cause death of tomato plants when grown in open field conditions, but under protected environment, the yield loss can be minimized (Cheema *et al.* 2013). Talisha *et al.* (2020) reported the effect of breeding methods and nitrogen fertilization on growth traits and tomato yield under the protected conditions. They concluded that the cultivation methods had no significant effect on plant height, stem girth, fruit size, and had a significant effect on root length in the plant. Two and three stem planting method displayed highest root length (36.67 and 37.56 cm respectively).

Tomato is a high value vegetable crop for off and main season production under protected conditions. The productivity of determinate tomatoes under open field condition is 400-600 q/ha, whereas, that of indeterminate tomatoes under polyhouse conditions is 2000-2400 q/ha. Since, the breeding for the protected conditions in India is still in infancy, farmers are forced to buy the hybrid seeds of indeterminate hybrids introduced from Israel or other countries at exorbitant prices of 1.50 - 2.00 lakh/kg every year. Tomato is susceptible to more than 200 diseases caused by pathogenic fungi (*Fusarium* wilt, *Verticillium* wilt, *Alternaria* stem canker, mildew), bacteria (Bacterial wilt, spot, speck), viruses (TYLCV, TLCV, TSWV, ToMV), or nematodes (Root knot nematode). Additionally, it is also susceptible to various abiotic stresses such as low and high temperature, flood, drought and salinity stresses. In protected structures, whitefly transmits viruses which are major constraints throughout the world (Dinuba *et al.* 2009). Over use of pesticides have resulted in pesticide-resistant variants of this pest, which are now associated with 20 different begomoviruses in tropical and subtropical regions of the world. Eleven different strains of begomoviruses have been reported in India.

In tomato indeterminate growth habit and single stemmed producing flowers and fruit continuously along the main stem are suitable for protected cultivation. These varieties reach to a length of 3040 ft in a 10-month season, thus sustaining protected tomato cultivation over a long period (Gazquez *et al.* 2017). In this crop the gene '*sp*' responsible for indeterminate character, '*cpt*' for compactness and many others genes like cf, I, I-1, Ph, Tm-1, Tm-2, Mi, Mj1 for various insect and disease resistance, hp (high pigment), B (beta carotene), nor (non-ripening), rin (ripening inhibitor) have been exploited for different characters and improved post-harvest life. Varieties can be developed using these favourable genes (Gazquez *et al.* 2017; Cheema *et al.* 2013). Other desirable characteristics include longer shelf life, high in nutrition (lycopene/carotene rich), photo-thermo insensitivity and processing attributes.

The most effective way to combat biotic stresses is adopting resistant genotypes. Stable resistant sources have been identified in cultivated and wild species and can be successfully deployed in to cultivated background through conventional and biotechnological methods (Kalia 2005). The genetics of different traits has thoroughly been studied in tomato.

Tomato bacterial wilt (*Ralstonia solanacearum*) is a serious threat for tomato production because of complex pathogen biology and lack of efûcient management measures. Moreover, resistance to bacterial wilt is quantitative and strongly influenced by the environment and therefore difficult to develop tolerant cultivars (Scott *et al.* 2005).Therefore grafting was practiced with suitable rootstock for bacterial wilt management in tomato (Lin *et al.* 2008) and has been proposed for open field and protected cultivation (King et al. 2008). Rivard and Louws (2008) found that rootstock 'CRA 66' and 'Hawaii 7996' (breeding lines) were the most promising for managing bacterial wilt. Furthermore, scion of 'BHN 602' grafted onto 'BHN 1054', 'Cheong Gang', 'BHN 998' or 'RST-04106-T' exhibited tolerance to bacterial wilt (Mcavoy *et al.* 2012). Grafting may cause a shift in the host specificity of the pathogen, emergence of a new pathogen, or both when a specific rootstock is used continuously for a long period of time in the production system (Garibaldi *et al*. 2008; Gilardi *et al.* 2014; Rivard *et al*. 2010).

In tomato, root-knot nematode (*Meloidogyne* spp.) causes severe problems in sandy soils under protected conditions. For the management of nematode, chemical method is very common, but alternative methods are used to avoid excessive use of chemicals. Nematode resistance is governed by single dominant gene (*Mi-1*) which is identified in the wild tomato, but the resistance breaks under high soil temperatures at >32^{0}C (Medina-Filho and Stevens 1980; Williamson 1998). Grafting is a sustainable and eco-friendly practice for nematode management. In the United States, Rivard *et al.* (2010) studied the response of tomato rootstock 'Big Power', 'Beaufort' and 'Maxifort' for management of root-knot nematodes in naturally infested soils and reported significant differences in root galling and root-knot nematode populations among rootstocks. Minimum root galling and nematode attack was recorded in 'Big Power' rootstock whereas 'Beaufort' and 'Maxifort' rootstock had a similar level of root galling in nongrafted or self-grafted plants. Lopez-Perez *et al.* (2006) identified resistant rootstocks, which retained yields under higher nematode infestation, but significant differences were reported in root galling and final nematode populations between rootstocks. Kunwar *et al*. (2015) demonstrated the use of grafting for managing root-knot nematodes in susceptible scion with resistant rootstock against bacterial wilt in tomato which shows the potential of grafting for managing multiple soilborne pathogens using the similar rootstocks. Grafting is one of the best alternative for sustainable crop productivity in nematode-infested soils.

Water stress is one of the most widespread and frequent abiotic stresses which drastically affect plant growth and development in many vegetable crops. Through breeding and molecular methods, tolerant or resistant tomato cultivars may be achieved, although such approaches demand a very long period to produce desired cultivars. Therefore, scientists identified that grafting is an alternative method to develop water stress tolerance in tomato (Nilsen *et al.* 2014). Kumar *et al.* (2017) recognized grafting for yield stability under water stress situations is the selection of rootstock with constitutive potential to increase yield rather than plant survival. Sanchez Rodriguez *et al.* (2013) reported superior growth and yield in grafted 'Josefina' scion under moderate water deficit was mainly due to the drought-tolerant 'Zarina' rootstock in Spain. Altunlu and Gul (2012) found that grafting of 'Beaufort' rootstock provides resistance to drought stress without having a negative effect on yield in tomato in Turkey. Nilsen *et al.* (2014) demonstrated that grafting of 'JjakKkung' rootstock reduced the vegetative growth of 'BHN 602' scion to conserve water while maintaining better photosynthetic activity under mild drought stress. Bhatt *et al.* (2015) found that grafting onto 'BPLH-1' 'Arka Keshav', 'MattuGulla' and 'Arka Neelkanth' developed higher physiological adaptation to water logging and gave relatively higher fruit yield in comparison with self or non grafted high-yielding tomato 'Arka Rakshak'.

In India polyhouse tomato breeding was started to develop the pure lines (PTP 1, PTP 2, PTP 3 and PTP 4) and F_1 hybrid (PTPH 1) having large fruit size (150-200g), thick pericarp (0.8-1cm), 4-5 fruits per cluster, long fruiting period (8-9 months), long plant height (20-25 feet's), potato leaf type have the ability to set fruits in wide temperature range (15-45^{0}C), resistant to fruit and shoot borer, long storage life under room temperature, indeterminate, single stemmed plants, medium sized bright colored fruits, short internodes, more number of fruits per plant, high TSS and acidity, thermo-insensitivity, resistance to whitefly and other important diseases and insect-pest.

Breeding for Capsicum

Sweet pepper is becoming an important item in our food because of food protective value in our health, nutrition and brings new flavours and taste to our food. Capsicum is a valuable crop with excellent prospect in protected environment (Greenleaf 1986). High cost of imported seeds is presently hampering the enthusiasm of small and marginal farmers. This can be boosted up by breeding indigenous varieties having cylindrical fruit shape and colour (green, red, yellow, orange), resistance to disease and insect pest especially, *Phytophthora* rot, anthracnose, mite, nematode, viruses and white fly, resistance to disorders like blossom end rot, cracking and flat shaped fruits, high yield potential, thermos and photo insensitivity and sturdy plants with indeterminate growth habit. The genes responsible for yellow and red colour fruits are preferred (Joshi and Berke 2005). The major challenge is to develop and breed new varieties indigenously with desirable traits suitable to greenhouse production simultaneously making the availability of their seeds at right time to the growers.

In Indian market, some hybrids like Indra, Bomby and Orobelle are dominating due to their colour, shape and yield parameters. Fast food and canning industries have wide demand of capsicum, varying in fruit shape (elongated to square), size (medium to large), weight (80-300 g), consistence, colour (green, red, yellow, and chocolate) and flesh thickness, different from the traditional varieties (green, four lobed and thick pericarp) being grown in open fields. To breed capsicum for protected cultivation, plant should have erect growth habit, shorter internodes and wider canopy. The early and late flowering contributes in prolonging the harvesting span. Sweet pepper is an often cross-pollinated crop and incorporation of parthenocarpy helps in enhancing the fruit set percentage (Joshi and Berke 2005).

Depending upon market demand, fruit shape for fresh marketing can be conical, blocky with four lobes, thick pericarp, without pungency and low seed content whereas, for processing (canning, pickling) fruit colour retention and flavour are important. Resistance to temperature (high and low), moisture stress and salinity can widen the adaptability of capsicum. Flowering and fruit set is the most susceptible stage for water stress in Capsicum. Flower and fruit drop, reduction in dry matter production, nutrient uptake and poor seed viability is the major impact caused by the water stress (Bosland and Votava 2012). Hence, to meet the requirement there is a need to strengthen indigenous crop improvement programmes aiming at breeding and development of high yielding superior cultivars in greenhouse peppers (Allard 1960).

Among biotic stresses, soil-borne pathogens particularly Fusarium wilt and nematodes cause rapid decline and severe yield reduction. Repeated cultivation inside the same structures year after year further aggravates the situation. Therefore, host plant resistance is the best alternative for capsicum cultivation in protected structures. Resistance from non-cultivated or small, hot chilli types can be introgressed into the bells. Commonly grown capsicum hybrids includes Indra, Orobelle, Triple star, Inspiration, Pasarella (Red), Bomby, Sunnyez, Yamuna (Green), Swarna, Bachata (Yellow), Natashaetc in India. The yield goes upto 896 to 1000 q/ha when the crop of capsicum is taken under polyhouse cultivation. The other varieties available are California Wonder, Arka Mohini, Arka Gaurav, Arka Basant, Bharat, Kt-1, Pusa Deepti, Solan Hybrid-1 etc. There is need to select hybrids with higher yield, uniform shape, size and longer growing period (8-10 months). Fruits should have characters such as four lobes, uniform colour and ripening with better shelf life.

The breeder must set objectives and specific targets as per the immediate market trends. The main general objectives in breeding of sweet peppers for greenhouse production are same as for outdoor breeding except few which require more attention like fruit quality in the form of shape, size, colour, pericarp thickness (exocarp), plant habit (Straight and upright) resistance to insect-pest and pathogens, earliness and vigour, high yielding potential, abiotic stress tolerance and plant morphology. In addition to general objectives of improving, there are several specific objectives for greenhouse peppers mainly uniformity of fruit, flavour and nutritional quality (Wani *et al.* 2011). Nowadays breeders attach increasing importance for quality nutrition to enhance the protective elements of peppers. Pepper is potentially an excellent source of antioxidants and other phytochemicals compounds, which has a favorable effect on human health. Many cultivars with high and uniform level of ascorbic acid, flavonoids and carotenoids are being developed in the country. Similarly, crop improvement teams are very concerned about the developing cultivars with disease and pest tolerance/ resistance. To achieve these objectives and to develop an ideal plant ideotype in this crop for growing under protected cultivation a strong and suitable breeding programme is created. Presence of diverse germplasm helps in breeding of novel varieties. The genus Capsicum also harbours incredible intra and inter-specific diversity in fruit type, shape, color, taste and biochemical composition (Sokova *et al.* 2013). Similarly there are many sources of resistance to various diseases and insect-pests and lines having tolerance to different stresses in the gene banks which are available throughout the world. AVRDC-The World Vegetable Centre maintain large number of accessions and collections in different countries (about 7500 base/active collections). Private seed companies in Asia and North America also maintains large collections to be utilized in their breeding programme. Similarly, Southern plant Introduction Station, Griffin, Georgia, USA under GRIN-Germplasm Resources Information Networks has approximately 3000 evaluated for different traits. There are many other institutes in the world like Centre for Genetic Resources, Wageningen, The Netherlands (CGN), Central Institute of Genetics and Germplasm, Gatersleben, Germany. In India, National Bureau of Plant Genetic Resources, New Delhi and Indian Institute of Vegetable Research mainly deals with the germplasm activity of Bell pepper/ Sweet pepper. These agencies also conduct various activities on their accessions including morphological and genetic diversity characterization using molecular markers and field evaluations to identify gene sources for increased yield and trait related crop improvement (Adetula 2006).

Breeding Methods

Mainly few classical methods are utilized in sweet pepper breeding. These include Selection, Pedigree method, SSD method, Backcross breeding, Recurrent Selection and heterosis breeding. The choice of the best method or their combination primarily depends on the type of inheritance (monogenic, oligogenic, or polygenic) of traits to be improved (Lee *et al.* 2013). Recently, use of biotechnological approaches has also emerged out to be a significant tool in developing cultivars or varieties within a less period of time and more efficiency and assured success. Marker-assisted breeding is also valuable for incorporating or introgressing specific desirable genes from wild relatives into domesticated varieties. Capsicum tolerates inbreeding, although there is some degree of heterosis for reproductive traits including seed yield components (Mishra *et al.* 1991). Open pollinated varieties have traditionally dominated home garden and commercial bell pepper cultivation. Nevertheless, in the last 30 years hybrid pepper for greenhouse production has attained commercial status (Poulos 1994). In bell pepper, hybrid varieties have been successfully developed. However, the major constraint of using these varieties for commercial cultivation is the high seed cost, because there is a lack of efficient and economic hybrid seed production technology. Due to greater susceptibility and congenial climate, it becomes hard to achieve the maximum yield potential of varieties (Kim 2014). Thereafter, indiscriminate use of pesticides for controlling diseases, insect-pests and nematodes is hazardous to the health and environment. Since, development of resistant or tolerant cultivars is one of the best options to minimize the losses due to disease/insect occurrence; there is urgent need to develop new cultivars having resistance to major diseases and insect-pests of pepper to be grown in the greenhouses (Pereira *et al.* 2011). However, understanding about resistance genes control and inheritance for many diseases is not clear as yet. Abiotic constraints pertaining to the climate (drought, flooding, strong winds, extreme temperature and sun light) and to the soil (moisture and nutrients content) may add up to biotic constraints and lead plants to stress and undergo anatomical and physiological disorders that reduce yield. One of the most common physiological disorders of pepper is blossom end rot, a calcium deficiency disorder that appears only at the blossom end of the fruit (Hochmuth and Hochmuth 2009). The threat of abiotic constraints is getting increasingly alarming as a result of population growth and climate change with expected greater adverse effects in vulnerable regions such as semi-arid West and Central Africa. The use of adapted varieties combined with careful crop management practices notably the control of root damaging factors, proper irrigation and nitrogen fertilization helps to control the effects of abiotic constraints (Hochmuth and Hochmuth 2009).

Important attributes of Polyhouse bred Capsicum includes earliness, superior fruit quality, resistance to diseases and insect pests, resistance to biotic and abiotic stresses (heat, water stresses, salinity, etc), regular flowering and fruiting for longer duration (8-10 months). Indeterminate growth habit with well-balanced plant having powerful vigour and consistency throughout the season. The fruits should have characters such as uniform size and shape preferably four lobes, fruit weight (>50 g), uniform colouring after attaining complete maturity, better shelf life (>than 5 days under ambient conditions) with short intermodal lengths (7 to 10 cm), maximum height (10 feet). Uniform blocky fruit with dark red colour, vigorous shoot growth are desirable Capsicum hybrids with high yield potential (>100 t/ha).

Breeding for Cucumber

Gynoecy has a positive effect on yield and constitutes a major component of cucumber improvement programs (Serquan *et al.* 1997) and this feature can easily be manipulated for production of F_1 hybrid seeds. Parthenocarpy with gynoecy in cucumber (*Cucumis sativus* L.) was reported long back by Sturtevent (1890). Parthenocarpy can be defined as the ability to develop fruits without pollination and fertilization. Parthenocarpy term was coined by Noll (1902) in cucumber. Parthenocarpic varieties out yield normal types by about 20 per cent and have better quality (Chen and Cao 1994). Utilization of parthenocarpic gynoecious lines in breeding programme favored maximum exploitation of heterosis in cucumber (Phillips 1999). Hybrid under optimum crop production and protection management, give economically more yield than improved varieties and also provides uniform size, earliness, better keeping quality and resistance to biotic and abiotic stresses (Kalloo *et al.* 2000). True breeding parthenocarpic lines in cucumbers are reported from GBPUA&T, Pant Nagar (Singh 2012), MPKV, Rahuri and IARI, New Delhi (More and Budgujar 2002). These lines were used for heterosis breeding programme for developing F_1 hybrids. True breeding gynoecious lines in cucumber are reported from University of Wisconsin, Madison, USA. India, being a native place of cucumber, possesses wide range of genetic variability for qualitative and quantitative characters (Munshi *et al.* 2007).

It is temperature sensitive crop suitable to grow under protected condition. Cultivation of parthenocarpic cucumber in greenhouses having partial environment control has been undertaken during last decade in our country. However, very little work has been done for developing varieties and hybrids for protected environment (Singh and Malhotra 2012). Thus, there was a need to develop and identify parthenocarpic gynoecious hybrids/cultivars suitable for protected cultivation in different seasons and regions of the country. Being a high value vegetable crop suitable to both protected and open cultivation, development of parthenocarpic gynoecious F_1 hybrids in cucumber help to boost the production and ensure more returns to farmers. Indeterminate type continues to grow until the plant dies, with the internodal length relatively constant throughout the length of the vine (Kumar *et al.* 2016). The growth habit are important in breeding programmes as these help in increasing yield and availability period to a greater extent. Ideotype breeding along with incorporation of useful genes for parthenocarpic character can be utilised on a large scale in polyhouses. Parthenocarpic gynoecious cucumber varieties are suitable for polyhouse cultivation as these varieties develop fruits automatically without any pollination (Karlsson 2016). Breeding effort should be concentrated on several fruit characteristics such as shape, colour, spine type (coarse or fine), spine colour (white or black), skin thickness and surface warts, high TSS, crispness, enhanced shelf life, resistance to biotic (downy mildew, powdery mildew, *Fusarium* wilt and root knot nematodes) and abiotic stress, highly responsive to fertilizer and photo and thermo insensitiveness (Bhardwaj 2017). The emphasis however is to develop parthenocarpic gynoecious hybrids. Gene '*Pc*' responsible for parthenocarpy, '*F*' responsible for short inter-nodal length can be utilized through pure line and back cross breeding methods to establish them in plant population in parthenocarpic cucumber (Hou *et al.* 1995).

Cucumber is mainly cultivated for salad purpose under protected conditions. It is a cross pollinated crop and do not set fruits without pollinators under the enclosed structures. Varieties for open field cultivation are monoecious in nature and generally bear female flowers from seventh or eighth node. Since, the enclosed structure will have limited number of cucumber plants, bearing of female flowers from lower nodes is important for higher production. Therefore, varieties must possess parthenocarpy and gynoecious traits for successful cultivation. Attractive green colour, cylindrical shape, tender skin, sweet (cucurbitacin free) and crisp fruits are demanded by the consumer (More and Munger 1986). Dry spell induces powdery mildew whereas; high humidity results in downy mildew inside the structures. An early and high yield fetches more returns to the growers. Resistance to Fusarium wilt, mosaic virus, powdery mildew, downy mildew and root knot nematodes are desirable to lower pesticide load and better quality of the produce (More 2002). Therefore, incorporation of genetic resistance along with desirable horticultural traits is the major concern for the cucumber breeders.

In cucumber, genotypes were identified and hybrid breeding programme were adopted for improvement of these genotypes. Two parthenocarpic cucumber, i.e. Pant Parthenocarpic Cucumber-2 and Pant Parthenocarpic Cucumber-3 and tomato variety Pant Polyhouse hybrid tomato-1 and Pant Polyhouse hybrid tomato-2 were released. In cucumber gynoecious parthenocarpic variety Pusa Seedless (DPaC-6) has been release by IARI for growing in protected conditions (More 2002). Likewise the efforts are going on to develop suitable varieties of tomato and capsicum for protected conditions. Besides, suitable new crops/ varieties are also being designed for protected environment, e.g. bitter gourd, summer squash, musk melon, long melon, chilli etc.

According to Kumar *et al.* (2016) the development of parthenocarpic gynoecious hybrids in cucumber (*Cucumis sativus* L.) has huge significance under protected conditions due to low cost of hybrids. Therefore, 48 F_1 crosses, developed by crossing 16 lines (8 gynoecious) with 3 testers during the year 2011 and the results revealed that lines LC-1–1, CGN-21585, LC-28–8, CGN-20953, and testers Japanese Long Green and K-75 were identified superior The cross combinations LC-1–1 × K-75 (monoecious), CGN-21585 × Japanese Long Green (gynoecious), CGN-19533 × K-75 (gynoecious), CGN-20953 × Poinsette (gynoecious), and LC-28–8 × K-75 (monoecious) were found the best on the basis of mean performance, specific combining ability, and heterosis. Estimates of SCA were higher in magnitude than those of GCA (average), thereby indicating the predominant role of non-additive gene action. Therefore, heterosis can be exploited commercially for high-yielding, quality parthenocarpic gynoecious hybrids development in cucumber under protected conditions.

Parthenocarpy is the development of ovary into seedless fruit without pollination and fertilization. It may occur naturally or induced artificially through exogenous application of hormones or their enhanced endogenous level. The majority of the studies which concerns the causes of abortion and parthenocarpy have focused on the four theoretical determinants for the study of the biological problems: causes (physiological, genetical, and ecological), development, evolution, and function (Verdu and Garcia-Fayos 1998). Several hypotheses were formulated regarding causes and function of abortion (Stephenson 1981), but parthenocarpy has received much less attention. Hypotheses in relation to abortion can be placed into three groups, (i) environmental uncertainty (ii) the male role of hermaphroditic flowers, and (iii) the improvement of the quality of seed produced through selective abscission (Stephenson 1981). The causes of parthenocarpy include frost damage to the ovule or stimulation by foreign pollen or changes in the competitive balance between vegetative and reproductive structures or a spatial or temporal failure on auxin synthesis. The role of parthenocarpy has also been considered as an exaptation related to the improbability of seed predation (Traveset 1993). Parthenocarpy circumvents the inhibitory effect of seed creation on succeeding fruit development. The fruit of parthenocarpic cucumber are mild in flavor, without seeds and have edible skin that requires no peeling while eating (Tiwari 2015). Chen and Cao (1994) overviewed that the evidence on the inheritance of parthenocarpy is conflicting, with reports of control by a single partially dominant gene *P* and by three independent major genes with additive and epistatic effects, as well as reports of inheritance typical of quantitative traits. Cucumber inbreds should be parthenocarpic gynoecious with shorter main vine length, short neck and dark green fruit with smooth surface. It should be tolerant to low temperature and weak light, short internodal length, high productivity, resistance to downy mildew, powdery mildew, anthracnose, mosaic and fruit fly. In cucumber, parthenocarpy and gynoecious sex expression is an asset under protected conditions.

Brinjal

Brinjal is suitable for cultivation in tropical and subtropical regions. It is sensitive to frost and highly prone to the attack of shoot and fruit borer. It can be saved from both these issues by cultivating under protected conditions. However, heterostyly nature of the flower lowers the fruit setting due to lack of pollinators and wind under the enclosed structures. Therefore, natural fruit setting ability without pollination is required in cultivar to grow under protected conditions. Though there is huge genetic diversity in brinjal with regard to shape, size, colour, taste and other fruit characteristics. The problem is to engross these favourable characteristics together in varieties or hybrids adapted to protected cultivation. The North-Indian varieties have great fertility, earliness and strong pigmentation, but when grown inside protected structures, which bears small, irregular shaped, soft and cotton-like textured fruits (Tuzel and Leonardi 2009). The varieties of the southern group however bear big fruits with acceptable yields but are slow in growth and succumb to various diseases. These noticeable varietal differences can be related to their specific transpirations.

The market demands for bright fruits with dark violet to black skin pigmentation and uniform coloured flesh but clubbing of these traits result in sour or pungent products. The white flesh varieties though are superior in taste, have a firmer flesh and can be harvested in a more leisurely way but lacks consumer preference in the market. As a result it is difficult to unite the favourable characteristics of colour and quality. Besides, erect growth habit of the plant, high yield, shining fruits in different size segments, low solanine, resistance to phomopsis blight, bacterial wilt, verticilium wilt, anthracnose, root knot nematodes, jassids and high and low temperature is desirable.

Brinjal is mainly infested by the insect-pests particularly shoot and fruit borer (*Leucinodes orbonalis*). It is difficult to control the insect-pests in the crop. The farmers in Karimganj district of Assam are using a huge quantity of pesticides, herbicide and fungicides for protection of the brinjal crop and better yield. They are being exposed to a large number of health hazards directly and indirectly. These people suffer from various chronic diseases like indigestion, gastric problems, weakness and low mental development. The existing pattern of pesticide usage, if continued, will result in undesirable effects, which include resource degradation, resurgence of pest populations, environment pollution and human health-hazards. Farmers are interested in cultivation of pest-resistant varieties which are not likely to develop in the immediate future. Therefore, protected cultivation of brinjal crop can be a promising technology and a better option to minimize the use of chemicals along with better quality fruits.

Cherry tomato

There is another segment called 'cherry tomatoes' which is considered as a high value crop. Cherry tomatoes (*Solanum lycopersicum* var. *cerasiforme*) are small sized fruits in clusters along with stem and branches of the plants. Cherry tomato is a smaller garden variety of tomato (Singh *et al.* 2014). The small-sized tomatoes are generally consumed as salads. Therefore, fruit size is important according to the consumer point of view. The breeding goals for the improvement of cherry tomato are higher yield, more fruit number, fruit shape, fruit weight, uniform fruit colour, earliness, fruit firmness, long shelf life, high TSS, solid to acid ratio and resistance to diseases and pests (Lenecci *et al.* 2006). Therefore, development of suitable cherry tomato varieties under protected conditions using suitable breeding method is one of the best approach. Dhaliwal & Jindal (2017) bred Punjab Red Cherry using interspecific cross between *Solanum lycopersicum* and *S. pimpinellifoilum* following the pedigree method of selection. The variety bred was indeterminate, with dark green foliage cherry tomato suitable for protected cultivation. The fruits of the variety are round, medium sized, sweet, deep red with good shelf life. Their results revealed that a mid-October planted crop in north Indian plains produced early fruit yield (late-March) of 39 Mt ha^{-1} and total yield of 109 Mt ha^{-1}. The variety is also tolerant to leaf curl virus and is suitable to the protected cultivation. Two indeterminate varieties of table tomato suitable for protected cultivation namely 'Punjab Gaurav' and 'Punjab Sartaj' have been recommended for commercial cultivation in the state by PAU.

Beans

In beans, the potential for self fertilization is 99%. The male and female organs are mature enough for fertilization and once the fertilization process is accomplished, the flower opens. The dry and hot weather during fertilization period have a negative impact on the fruit set. In case of beans, gene conferring pole type characters rather than bush type can be exploited for polyhouse cultivation. A morphogenomic concept is defined as a result of the interaction of several characters that determine the final plant architecture. These characters are type of growth of stem and branches i.e., determinate or indeterminate, number of nodes on the stem, length of the internodes, climbing ability and branching pattern (position, number and length). Four types of beans viz., bushy and determinate, bushy and indeterminate, indeterminate prostrate with well developed branching having low ornon existence climbing ability, indeterminate with long guide and high climbing ability. Varieties should have higher pod yield, non stringy, long pods, flat or round in shape, early pod harvesting, pole type plant, high number of green pods/plant, high number of pod clusters/plant, higher number of primary branches/plant, free from interlocular space, photo-insensitivity, wider adoptability, resistance to diseases and insect pests. The varieties commercially grown and available in India on a large scale under bush type are Contender, Pusa Parvati, VL Boni 1, Arka Komal, Pant Anupama and Pant Bean 2 (UPF 626) and under Pole type are Kentucky Wonder and Canadian Wonder.

Other potential crops

Vegetables like spinach, lettuce, celery, brussels sprout, chinese cabbage, coriander etc have high economic potential under protected conditions, particularly during off-season (Kohli *et al.* 2010). Varieties of leafy vegetables that grow faster under low light conditions, offers more number of cuttings, better quality and higher yield are ideal. Spinach variety should be early yielding with multiple harvesting, adaptive to protected conditions, resistant to insect-pest and diseases, low light intensity (UV-B) and other environmental factors. Lettuce is commercially consumed throughout the world mainly as salad or in sandwiches (La Malfa and Leonardi 1993). Lettuce is susceptible to number of diseases and pest. Downy mildew is serious problem and resistant cultivars have been bred against newly evolving virulent strains of this pathogen (Irish *et al.* 2008). The resistance was reported to be governed by *Dm* loci with multiple alleles. Big vein disease caused by virus and transmitted by root inhibiting fungus (*Olpidium brassicae*) (Heuberger *et al.* 2004). Celery is a salad crop mainly grown for its long fleshy stalk. In India, maximum area is in Punjab and Uttar Pradesh, whereas, it is commercially grown in USA, France and other European counties (Quinos 1987). The main breeding objectives regardless of varietal type are higher quality, yield, uniformity, slow bolting and disease resistance (Morelock and Correll 2005). The uniformity is in term of colour, size and texture. The leaf should be free from cracking, pithiness and stringiness (Epstein *et al.* 2017). Diseases like fusarium wilt and blight are of major concern. Four races of *Fusarium oxysporum* f. sp. *apii* were identified. A partial dominance in *A. panul* and *A. chilense* has been observed for late blight resistance while early blight is governed by more than one gene.

Brussel sprout (*Brassica oleracea* var. *gemmifera* DC.) is cultivated for sprouts or buttons (swollen buds). The architecture of plant variety depends on early maturing and greater number of sprouts. Until stem reached to its height, sprouts do not develop while taller plants have greater number of sprouts with small size. So the objective for protected structure must be earliness with greater height and without lodging (Yuen 1991). TuMV resistance was controlled by 4 genes, which are highly heritable (Feng *et al.* 2018). While, resistance to cauliflower mosaic virus is generally dominant. However, presence of some recessive genes has also been reported. Among insect, cabbage aphid (*Brevicorne brassicae*) is a serious problem. Chinese cabbage is mainly grown as a salad crop (Green 1986). The main breeding objectives are early, higher yield with resistance to biotic and abiotic stresses (Feng *et al.* 2014). Cold and heat tolerance along with slow bolting behaviour are desirable for protected conditions. Downy mildew resistance is controlled by two dominant genes (Mero 1983).

Grafting for biotic and abiotic stresses

Grafting is largely used in Cucurbitaceae and Solanaceae species and is rapidly spreading and expanding all over the world. Efforts are being made by public and private sectors to develop tomato cultivars which have the capability to perform better under different situations through molecular approaches, which requires considerable time. One alternative approach is grafting, which emerged as a potential tool to quickly enhance the efficiency of high-yielding genotypes for wider adaptability or resistance to different stresses (Kumar *et al.* 2017). Vegetable grafting has become a potential tool in boosting the production of fruiting vegetables of solanaceae and cucurbitaceae families (Lee *et al.* 2010). Grafting in tomato was commenced in 1960s and recently become an important cultivation practice for the tomato crop in many parts of the world (Lee and Oda 2003). This technique produces plants that are more vigorous, the initial objective being protection against soil-borne diseases and soil fatigue provoked by successive cropping (Lee *et al.* 2010). Accordingly, the use of grafted plants permits some cultivars to be grown in non-disinfected soils following the banning of methyl-bromide as fumigant (Lopez Marin *et al.* 2013). Grafting helps to combat various types of stress tolerance, increasing the yield and duration of crops and enhancing crop quality. Nowadays, rootstock breeding for vegetable crops includes other desirable traits such as compatibility with the scion, enhanced the quality and productivity under stress conditions and improved the use of various resources viz., soil, water and fertilizer resources (Lopez-Marin *et al.* 2017). Accordingly, grafting is frequently used as an alternative to breeding programme in horticultural crops since compatible rootstocks can improve plant performance by enhancing nutrient uptake (Martinez-Andujar 2017). Finally, the use of grafted plants can affect the product quality.

Scientists have reported different effects of grafting on fruit quality in tomato. Kumar *et al.* (2015) demonstrated that fruit quality traits such as skin color, fruit shape index, titratable acidity (TA) and dry matter are positively affected by the rootstock. Turhan *et al.* (2011) observed that the tomato fruit quality attributes such as lycopene content and pH were not affected with grafting, whereas ascorbic acid, titrable acidity and SSC were reduced in grafted plants. Vrcek *et al.* (2011) observed that vitamin C, phenolic and antioxidant activity decreased in tomato with grafting.

Therefore, grafting may also be used to supplement tomato classical breeding programs. Future efforts in tomato rootstock breeding should take into consideration the adjustment of rootstock to specific environments, resistance to insects and foliar diseases, improved resistance to abiotic stresses, and increase fruit quality. Most of the tomato grafting employed for pathogens are primarily designed for a specific pathogen except few, where rootstocks provide resistance or tolerance to multiple pathogens. Therefore, there is need to promote the research for managing disease with grafting in tomato. In addition, most of the grafting researches are from greenhouse production systems, and limited information on compatibility with open-field cultivars and field performance of grafted plants in various climatic conditions (Kubota *et al.* 2008). Therefore, investigations should be explored to estimate rootstock performance and compatibility in open-field systems for wider perspectives of the application of this technology.

Grafting is novel approach to combat biotic and abiotic stresses. Soil borne diseases like verticilium wilt, bacterial wilt, fusarium wilt, corky root etc. and nematodes are some of the biotic stresses cause huge damage in vegetable production especially in continuous cropping of greenhouses (Lee *et al.* 2013). Pepper scion i.e. Nokk wang grafted onto breeding lines viz.,PR 920, PR 991 and PR 922 resistant to *Phytophthora* blight and bacterial wilt exhibited higher survival rate when inoculated with *Phytophthora capsici* and *Ralstonia solanacearum* (Jang *et al.* 2012).Grafting is an effective approach to improve fruit quality under the optimum growth conditions. The fruit quality of shoot depends on the root system (Flores *et al.* 2010). In soil less cultivation, grafted plants displayed higher yield and fruit quality in tomato. Grafting of eggplant onto *S. torvum* improved the fruit size without influencing the fruit quality and yield. Various parameters viz., Colour, sugar, texture, flavor and carotene content was influenced with grafting and type of rootstock used (Davis *et al.* 2008). It has been reported that solute content was significantly associated with fruit quality are translocated in the scion through the xylem, whereas quality traits, e.g. fruit shape, skin colour, skin or rind smoothness, flesh texture and colour and soluble solids concentration are influenced by the rootstock. In contrast, grafting eggplant on *Solanum torvum* and *Solanum sisymbrifolium* negatively affected vitamin C content, firmness and some sensory attributes but overall impression was not influenced (Nuez 1986). Researchers recorded no significant differences in total soluble solids by tomato "Oxheart" grafted onto two inter-specific *S. lycopersicum* × *S. habrochiates* and found that vitamin C content was decreased by 14-20 % if tomato plants grafted onto Beaufort F_1 and Maxifort F_1. So, there is need of further research regarding improvement of qualitative traits via grafting techniques under protected conditions.

Varieties for protected cultivation

World over, capsicum, cucumber, tomato are the favourite crops in greenhouses. Coloured capsicums, parthenocarpic and gynoecious cucumbers, cherry tomatoes are extensively grown. Huge genetic diversity available in cultivable and wild species of these crops has been exploited by conventional, biotechnological and genetic engineering techniques to develop cultivars suitable for protected cultivation (Campbell and Grogan 1963). A trend of growing brinjal in net house is building up gradually especially in Punjab, Haryana and some parts of Uttar Pradesh of India.

Conclusion

It is imperative that vegetable varieties are bred for adaptation to protected environment, as great diversity of climatic conditions exists in such conditions. There is a variation in each location during the growing season and changes can occur very rapidly. Therefore, it is necessary to breed varieties with wider adaptation to climatic conditions. Main research efforts in breeding of vegetable cultivars for protected conditions have to be focused on screening and evaluation of breeding materials for tolerance to low temperature & low light conditions, and resistance to diseases. Besides, emphasis has to be on creation and development of new breeding materials for protected conditions by selection, introduction, and crossing and biotechnological methods including isolating from F_1 genotypes, wide crosses, tissue and cell culture, protoplast regeneration, and gene transfer techniques (Meng *et al.* 1999). For enhancing breeding efficiency the focus is required on marker assisted selection as it would be helpful in pyramiding genes of interest to desirable genetic background in different vegetable crops to be grown under protected conditions. The greenhouse/ protected cultivation technology requires concerted efforts from all concerned agencies to bring it at par with the global standards. Economically viable and technologically feasible greenhouse technology suitable for the Indian agro-climatic and geographical conditions is needed.

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