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Review

Genetic improvement of bell pepper under protected structures- a review

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ABSTRACT

Bell pepper, commonly known as sweet pepper or capsicum, is the most important commercial and high value vegetable crop rich in vitamin C mainly grown in Asia, Africa and South America and domesticated throughout the world. Cultivation of bell pepper under protected structure is spread all over the world. In Indian scenario the cultivation of bell pepper is increasing steadily under naturally ventilated polyhouse. Genetic improvement programme of crop involves several activities such as germplasm conservation, evaluation of genetic diversity, selection of promising genotypes/hybrids, progenitor's selection, hybridization and evaluation of segregating populations. The major objective is for high productivity of quality produce during off seasons with minimum usage of pesticides. Bell pepper has a tendency towards autogamy even though it is hermaphroditic in nature. Besides conventional breeding methods, molecular genetics, tissue culture and genetic engineering are becoming increasingly important. There is need to develop quality enrich hybrids/varieties of bell pepper.

Keywords: Bell pepper; protected structure; fruit yield; selection; quality traits

INTRODUCTION

Bell pepper (*Capsicum annuum* L var *grossum* Sendt), a member of family Solanaceae, commonly known as sweet pepper or capsicum or Shimla Mirch, is native of Mexico with secondary centre of origin in Guatemala (Bukasov 1930). Bell peppers have a glossy exterior of different, vivid colours including green, red, yellow, orange, purple brown to black. Green peppers are unripe bell peppers while the all others are ripe with colour variation based on cultivar selection. It was introduced in India by the British in the 19th century in Shimla hills. Globally it is cultivated over an area of 1.99 m ha with the production and productivity of 38.09 m tonnes and 19.10 tonnes respectively including hot pepper (http://www.FAOstat.fao.org.com). China is its world's largest producer followed by Mexico. In India it is cultivated over an area of 0.024 m ha with the production and of 0.33 m tonnes (Anon 2018). Bell pepper is grouped under non-traditional category of vegetables (Kalloo and Pandey 2002). In India it is commercially grown in Himachal Pradesh, Jammu and Kashmir, Uttrakhand, Arunachal Pradesh and Darjeeling district of West Bengal during summer months and as an autumn crop in Maharashtra, Karnataka, Tamil Nadu and Bihar. Of late bell pepper has attained a status of high value crop and occupies a place of pride among vegetables in India because of its delicacy and pleasant flavour besides being rich in fatty acids, flavonoids, volatile oil and carotene. It is rich in ascorbic acid and zinc which are vital for a strong and healthy immune system. It is also rich in vitamin A, rutin (a bioflavonoid), beta-carotene, iron, calcium and potassium. It also contains magnesium, phosphorus, sulphur, B-complex vitamins, sodium and selenium (Agarwal et al 2007). Sweet peppers are low in calories, high in complex carbohydrates and contain no fat. Fruits are good source of dietary fibre, folate and manganese. Adequate consumption of green and red sweet peppers provides protection against prostrate, cervix and lung cancer. Bell pepper sells at premium price in urban markets mainly due to its ever-increasing demand. It also offers promise for export. Fruits of bell pepper are generally blocky, square and thick fleshed, three to four lobed with low to mild pungency. There are several uses of bell pepper viz salad, stuffing material, cooked vegetable, pickled or processed and appreciated worldwide for its aroma, flavour and colour. There is a good demand for its export and the export market requires fruits with attractive colour, mild pungency and good taste. However the supply is inadequate due to the low productivity of the crop. Vegetable growers are raising this crop since the crop grown under open conditions does not fulfill the urban market standards due to prevalence of various biotic (pests and diseases) and abiotic (heavy rains, low and high temperature, high relative humidity and low light intensity) stresses. Growing of bell pepper under protected structures ensures higher yield with better quality produce than open environment. Genetic variability is the foremost requirement in the successful execution of any crop improvement programme. It is important to partition the genetic and environmental components of variability as well as the correlations between different yield attributes into direct and indirect components so as to focus on specific traits while effecting genetic improvement.

The breeding objectives of bell pepper include quality fruit yield, indeterminate growth habit of plants, early fruit yield, development of uniform colour (yellow and red), biochemical trait rich cultivars, resistance against biotic stresses etc. Selection of breeding method for bell pepper depends on the breeding objectives and the germplasm being used as parents (Greenleaf 1986). The strategy of the breeder is to assemble into a cultivar the superior genetic potential for quality yield, protection against production problems and improved quality. Cultivars have been developed using morphological selection within introduced lines/cultivars and hybridization followed by selection. Selection methods include mass, single plant, backcross and pedigree. Pure lines showing resistance against biotic (diseases, insects, nematodes etc) and abiotic (environment and soil conditions) stresses are selected during routine breeding process. The breeding technique with limited success is genetic transformation. The rates of out crossing (7 to 91%) recorded by several investigators argue that bell pepper should be considered to be often cross-pollinated species in field research (Odland and Porter 1941, Franceschetti 1971, Tanksley 1984).

The out-crossing is associated with natural insect pollinators. The amount of cross pollination has an effect not only on the precautions needed for seed production but also on the breeding methodologies used by the plant breeder (Bosland 1993).

Genetic improvement through selection based on morphological traits

To ascertain the nature and magnitude of observed variability in the hybrids it was partitioned into phenotypic, genotypic and environmental components. The knowledge of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) is helpful in predicting the amount of variation present in the given genetic stock which in turn helps in formulating an efficient breeding programme. Wide variations were observed among the genotypes for the characters studied. Fruit set varied from as low as 63 per cent in CA 018 to as high as 90.66 per cent in CA 016. The longest fruit length was observed in fruits of CA 016 (16.20 cm) and the fruit of the genotype CA 015 (6.80 cm) was the shortest followed by the genotypes CA 019 (8.60 cm) and BARI Mistimorich-1 (8.70 cm). Maximum number of fruits per plant and fruit yield per plant were observed in CA 016 (Sattar et al 2015). Farooq et al (2015) reported that the hybrid namely Orobella ranked first regarding number of fruits per plant, fruit weight per plant and yield followed by Figaro and Capistrano respectively under plastic tunnel. High genetic diversity was observed amongst the lines and a total of 13 clusters were observed. The inter-cluster D^2 value ranged from 3.54 to 13.60 indicating that the selected accessions were genetically divergent. The genetically more divergent lines were present in clusters 5 and 8 as indicated by maximum inter-cluster distance value (13.60) which offer promise as a breeding stock in hybridization for the isolation of better transgressive segregants in bell pepper (Devi et al 2017).

Under protected cultivation hybrid Bachata was found promising for fruits per plant, fruit set, fruit yield per plant, fruit yield per meter square and fruit yield per hectare (Manoj and Venugopal 2018). The PCV was invariably higher than their corresponding GCV for most of the characters indicating close association between phenotype and genotype. High PCV as well as GCV were observed for fruit yield per plant, fruits per plant, marketable fruit yield per plant, marketable fruits per plant, capsanthin content and ascorbic acid depicting the presence of substantial variability and would respond better to selection. High heritability along with high genetic advance was observed for fruit yield per plant, fruits per plant, marketable fruit yield per plant, marketable fruits per plant, capsanthin content, TSS and ascorbic acid revealing the importance of additive gene action for the inheritance of these traits and further improvement could be done through phenotypic selection (Thakur et al 2019). Bhattarai et al (2020) reported that California Wonder has a potential to grow under protected structures. California Wonder had lowest physiological weight loss at different days after harvest. This study recognized HRDCAP-001 to be a promising genotype. Hence there is a possibility to release this genotype as a variety for commercial cultivation. However a multi-location trial prior to its release is deemed necessary. Furthermore all evaluated genotypes through this research could be utilized for capsicum breeding.

Selection for quality traits

Hybrid-5 and Hybrid-7 are the most promising for quality traits as these contain higher values for ascorbic acid, colouring matter and pericarp thickness (Choudhary et al 2011). The capsicum hybrid Angel and the variety Arka Gaurav which produced yellow coloured fruits were rated superior in quality as they recorded higher values of ascorbic acid and TSS. Total carotenoid content was high in the hybrid NS-280 which produced red coloured fruits. The hybrid Indra and the variety Royal Wonder had thick walled fruits and hence suitable for long distant transportation. In fact lower capsaicin, high ascorbic acid content and chlorophyll content are desirable biochemical attributes and hybrids Orobelle and Bomby for ascorbic acid content, Indam Mamatha and Bachata for chlorophyll content and hybrids Bachata and Indam Mamatha for low capsaicin content offer promise (Kumar et al 2015). The capsicums with thick fruit wall also retain firmness for a longer period (Narayan et al 2015). Hybrid Bachata was found promising for qualitative parameters like shelf-life, higher pericarp thickness and maximum dietary fibre content. The maximum vitamin C content was recorded by Orobelle. The minimum moisture content was recorded by Bachata, Inspiration, Sympatty and Orobelle (Manoj and Venugopal 2018).

Genetic improvement through heterosis breeding

The genetic improvement by increasing productivity in the quickest possible time can be achieved by utilizing heterosis breeding. After reporting the phenomenon of heterosis by Shull (1914) many-fold improvements have been made in various aspects of exploiting heterosis in vegetable crops. A F_1 hybrid variety is the offspring of a cross between two different parents. The prerequisite is that all the F_1 plants should resemble each other phenotypically. Capsicum has a tendency towards autogamy and even though it is hermaphroditic in nature, self-fertilization cannot be avoided to 100 per cent. For exploitation of heterosis combining ability analysis is necessity, the well combiner produces good off-springs. Parental lines viz UHF-11, UHF-6, UHF-14 and UHF-10 were found good general combiners for majority of traits and SCA performance showed that the cross combinations UHF-8 x California Wonder, UHF-10 x California Wonder, UHF-11 x Solan Bharpur and UHF-6 x Solan Bharpur were found best for majority of yield and yield contributing traits under protected conditions and may be utilized for development of capsicum hybrid for protected conditions in mid-hills of Himachal Pradesh (Kaur et al 2018). Aditika et al (2020) reported that California Wonder and Solan Bharpur parental lines were found to be the best combiner for earliness whereas Yolo Wonder, California Wonder, Nishath-1 and UHFBP-3 reported as best parental lines for fruit quality, yield and yield contributing traits based on their general combining effects. Solan Bharpur × Yolo Wonder, Yolo Wonder × Nishath-1, California Wonder × Solan Bharpur, California Wonder × UHFBP-3 and UHFBP-3 × KC-12 cross-combinations were found outstanding based on heterosis and specific combining ability for most of the traits under net house condition. The hybrids illustrated the presence of over-dominance effect for yield and yield contributing traits. Predominance of non-additive gene action for all the characters suggested the usefulness of exploitation of hybrid vigor.

Genetic improvement through marker assisted selection

Marker assisted selection can be practiced more efficiently for characters whose phenotypic selection is difficult. For example transferring a fertility restorer gene from one line to another line through backcrossing needs test crossing before subsequent backcrossing. If such genes are tagged with molecular markers, desirable plants with fertility restorer gene (in heterozygous condition) can be identified and backcrossed. Similarly screening for abiotic stresses is very difficult. If desirable genes conferring tolerance to abiotic stresses are tagged, these can be selected easily in segregating generations. Also genetic markers can be assayed in non-target areas such as growth chamber, green houses or off-season nurseries thus permitting more rapid progress. The efficiencies of scale and time accorded by DNA markers are valuable in breeding most species but are of special value in breeding species that have large stature or long generation time (such species as orchard or forest trees) where fewer individuals might save several hectares and fewer generations may save several decades (Paterson et al 1991).

CONCLUSION

Cultivation of vegetable cops under protected structures offers distinct advantages of quality, productivity and favorable market price to the farmers. Farmers can substantially increase their income by protected cultivation of vegetables in off-season as the vegetables produced during their normal season generally do not fetch good returns due to glut of these vegetables in the markets. In India genetic improvement of bell pepper cultivars specially designed for cultivation under protected structures is a new area and less work has been done to develop varieties/ hybrids.

Presently whatever hybrids are available are supplied by private seed companies and they are fleecing the greenhouse growers by charging exorbitantly. Therefore there is need to develop/breed indigenous location specific hybrids/varieties suitable for protected structures having multiple and multigenic resistance. Bell pepper varieties have evolved from local land races to advanced hybrid development. Use of biotechnology will likely aid in the future development of improved bell pepper varieties/hybrids. Besides conventional breeding methods, molecular genetics, tissue culture and genetic engineering are becoming increasingly important. There is need to develop productive with quality enrich hybrids/varieties in bell pepper.

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