Potential, Challenges and Strategies Involved in Gene Introgression from Wild Relatives of Vegetable Crops: A Review

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ABSTRACT

Wide hybridization is an important plant breeding method as it helps in broadening the gene pool of a crop when the desired variation is not sufficient or absent within the same gene pool. Wild genetic resources are the potential source of desirable genes for various characters of crop plants. It plays a significant role in transferring traits of interest like disease and insect resistance, improved quality, earliness, dwarfness, increased yield, abiotic stress tolerance and manipulation in mode of reproduction etc. in crop plants. It has been instrumental in transferring disease resistance from wild species into many vegetable crops. For example, resistance to late blight, leaf roll and potato virus X, yellow vein mosaic virus and powdery mildew in okra, bacterial wilt, tomato leaf curl virus, early and late blight in tomato has been transferred from wild species into cultivated species. Wild species has been used to improve the quality traits of some crops like carotenoid content in carrot and tomato, starch content in potato etc. Sometimes distant hybridization leads to creation of entirely new crop species. Chromosome elimination technique followed by wide hybridization has been successfully used in the production of double haploids in some crops. However there are some lacunae in wide hybridization such as cross incompatibility, hybrid inviability, hybrid sterility and hybrid breakdown. Some special techniques viz. ploidy manipulation, pistil manipulation, growth regulators treatments, bridge crossing, grafting and embryo rescue have to be adopted to make distant hybridization successful in such cases.

Key words: Abiotic stress tolerance, Distant hybridization, Disease resistance, Quality improvement, Vegetable.

Hybridization between individuals from different species belonging to the same genus or two different genera, is termed as distant hybridization or wide hybridization and such crosses are known as distant crosses or wide crosses. When individuals from two distinct species of the same genus are crossed, it is known as inter specific hybridization and when individuals being crossed belong to two different genera, it is referred to as inter generic hybridization. The first distant hybridization was made between carnation (Dianthus caryophyllus) and sweet william (Dianthus barbatus) by Thomas Fairchild in 1717 and the hybrid was known as fairchilds mule (Singh, 2009). Vegetables are important protected food that provides vitamins and minerals. Nutritional security of developing and underdeveloped countries heavily depends upon vegetables. Allied species of different vegetable crops such as wild, semi-wild and semi-cultivated carrying resistance to diseases, insect pests, stress environment and rich in quality attributes are being exploited continuously for breeding purpose. For example carotenoid content in carrot and tomato, starch content in potato etc. have been improved through the use of their wild relatives. Adaptation to various environmental conditions has been improved through the use of wild species. For example, tolerance to cold in onion, potato, beans and tomato has been transferred from wild species of these crops. Wild species are useful in vegetable breeding for various characteristics.

Disease and pest resistance

Vegetables are major constituents of Indian diet and insect pests and diseases limit their productivity, reduce the crop yield, quality and crop returns. Most important objective for crop improvement in vegetable crops is tolerance to biotic stresses. Identification of resistance sources and their use resulted in substantial gains in crop productivity. Distant hybridization has been instrumental in transferring disease resistance from wild species into cultivated ones. For example, resistance to late blight, leaf roll and potato virus X, yellow vein mosaic virus in okra has been transferred from wild species of these crops into cultivated species. In tomato resistance to bacterial wilt, canker, fusarium wilt, grey leaf spot, leaf mouds, verticillium wilt, curly top virus and mosaic virus has been transferred from wild species to commercial cultivars. Resistant lines for powdery mildew in okra were developed by crossing A. esculentus with A. manihot ssp. manihot (Jambhale and Nerkar 1992). In some
potentially improves the quality of cultivated ones.

**Case studies**

**Distant hybridization for brinjal fruit and shoot borer**

*Leucinodes orbonalis* is the major insect pest of eggplant, *Solanum melongena* L., locally known as brinjal, throughout Asia. Larvae bore into shoots during the vegetative growth stage and later in flowers and fruits, rendering fruit unfit for human consumption. In the past, brinjal was regarded as a cheap vegetable, available throughout most of the year, but production is now seriously affected in many parts of the Indian sub-continent by the high cost and low efficacy of insecticide needed to ensure production of a viable crop. In order to incorporate the resistance to the cultivated eggplant interspecific hybridization between *Solanum melongena* and *Solanum macrocarpon* and reciprocals were carried out. To overcome the sterility in *F₁* hybrids of *S. melongena* × *S. macrocarpon* and reciprocals, the *F₂* hybrid seedlings were treated with 0.5 per cent colchicine to induce amphidiploids and this study is in progress (Rao 1981). When *S. Khasianum* was pollinated by *S. melongena*, pollen tube growth ceased before penetration in the ovary. In the reciprocal cross, a few ovaries were fertilized but subsequently the embryos degenerated. When excised embryos were cultured in vitro, fertile plants were regenerated successfully. The *F₁* generation exhibited the spiny phenotype of *S. khasianum*. *F₂* segregates into spine and without spines. This species is found resistant to *Leucinodes orbonalis* and may be used, with the help of embryo culture, to introduce resistance into *S. melongena* (Sharma et al. 1980). Resistance of interspecific crosses (among *Solanum incanum*, *S. indicum*, *S. gilo* and *S. melongena* cultivars *Annamalai*, *Aushey* and *Pusa Kranti* and resultant hybrids (*Pusa Kranti* × *S. incanum*, *Pusa Kranti* × *S. indicum*, *Pusa Kranti* × *S. gilo* and *Aushey* × *S. gilo*) to *L. orbonalis* was studied. The highest frequency of univalent coupled with high degree of sterility in these hybrids indicated the high degree of dissimilarities of parental chromosomes. The low frequency of chiasma further revealed the lack of homology between genomes (Bahera and Singh, 2002).

**29-D, A Melon Inbred with Multiple Diseases Resistance**

*Cucumis melo* line PI 124111F was stabilized for resistance to downy mildew, powdery mildew race 1 and 2 and *Fusarium* wilt races 0, 1 and 2. This line was crossed to a susceptible *Ha'ogen* type and then backcrossed to a susceptible orange-flesh cantaloupe. 29-D was selected after 10 generations of selections and selfing. 29-D is resistant to downy mildew caused by *Pseudoperonospora cubensis*, powdery mildew caused by races 1 and 2 of *Sphaerotheca fuliginea* and races 0, 1 and 2 of *Fusarium oxysporum f. sp. melonis*. This inbred line produces a vigorous vine with globular, netted and sutured fruits. The fruits have a small cavity and mild orange flesh. 29-D combines beautifully with various partners such as ananas types, cantaloupes and charantias. *F₁* hybrid plants are resistance, under field conditions, to downy mildew, powdery mildew race 1 and *Fusarium* wilt. Resistance to race 2 of powdery mildew is incomplete (Cohen 1999).

**Development of breeding lines of muskmelon resistant to fruitfly**

50 *Cucumis melo* accessions from India and other regions were screened for resistance to *Dacus cucurbitae* in the field over 4 years. 6 accessions (all from India or Afghanistan) were characterized as resistant or immune (0-10% fruit damage) to fruit fly. The resistant accessions were similar to the commercial variety *Arka Jeet* in many respects, but low in total soluble sugar contents. Data from a cross between *Arka Jeet* and the resistant wild species *C. callosus* indicated that resistance may be dominant. Incorporation of resistance from *C. callosus* into *Arka Jeet* by backcrossing is recommended for breeding resistant varieties with good horticultural attributes in muskmelon (Pal et al., 1983).

**Breeding for disease resistance in Tomato**

*Tomato* (*Solanum lycopersicum* L.) is one of the most important crops grown throughout the world. It is facing a lot of challenges against production such as biotic and abiotic stress which cause the reduction of yield. Abiotic stress such as temperature, frost, heat, drought and biotic diseases and insects are severely damaging its quality and yield. Wild relatives of cultivated tomatoes include *S. pennelli*, *S. peruvianum* and *S. pimpinellifolium* have resistant genes against many biotic and abiotic stresses (Muhammad, 2019). Losses in tomato yield can be as high as 75% to 100% due to Tomato Spotted Wilt Virus (TSWV). If infection starts 10 to 30 days after transplanting, the yield loss will be 100%. Resistance to TSWV is heritable and can be transferred to cultivated tomatoes from wild species. Some introductions of *L. peruvianum* were found to be resistant to TSWV. But a high level of incompatibility between these lines and *L. esculentum* limit their utilization in tomato breeding programs. After 25 days after pollination all the embryo had aborted. Therefore attempts were made to excise 15-25 days old embryo and culture under in vitro conditions. *F₁* hybrids between *Lycopersicon esculentum* and *L. peruvianum* can be obtained through immature embryo culture. This in vitro technique was first used by Smith in 1944 to transfer nematode resistant gene *Mi* from *L. Peruvianum* line PI 128. 657 to commercial tomato cultivars (Segeren et al. 1993). Four lines resistant to early blight (*Alternaria solani*) were bred by interspecific hybridization and backcrossing of *L. esculentum* with *L. pimpinellifolium* (to give line P1) and *L. hirsutum f. glabratum* (to give lines H7, H22 and H25) (Kalloo and Banerjee, 1993). Different lines viz. H2, H11, H17, H23, H24 and H36, resistant to tomato leaf curl virus, were developed by controlled introgression of *L. hirsutum f. glabratum* into *L. esculentum*. Disease incidence ranged from 8.3 to 35.0%, whereas in susceptible varieties it ranged from 95.0 to 100%. Values for the coefficient of infection...
(Cl) in the resistant lines were very low, ranging from 0.25 to 4.55, whereas in susceptible varieties it ranged from 60.6 to 89.0. Line 
H2 had the highest resistance, showing the lowest disease incidence and Cl values. Fruit size and days to fruit maturity in the resistant lines were close to those of cultivated susceptible varieties (Kalloo and Banerjee 1990).

Distant hybridization in the genus Cucumis using bridge crosses and embryo rescue

This hybrid between C. melo var. agrestis and C. melo var. flexiosus was used as a bridge to overcome cross incompatibility in hybridizing cultivated cucumber with wild species. When the F1 was crossed with cucumber line Zk3, the fruit obtained generally had unfertilized ovules. F1 hybrid between cucumber and C. sativus var. rigidus and C. sativus var. sikimensis was produced and tested for resistance to powdery mildew (Sphaerotheca fuliginea). The hybrids showed an infection percentage of 53.3-87.5% compared with 38.2% in the pollen parent. Interspecific hybridization of C. anguria × C. zeyheri, C. sativus × C. melo and C. sativus × C. metuliferus with the use of embryo culture protocols was carried out and cross-pollination between C. anguria and C. zeyheri was found successful (Skalova, 2007).

Resistance to Alternaria leaf spot in Brassica species

Resistance to A. brassicaceae was transferred from a resistant B. carinata accession to the widely cultivated but susceptible Indian mustard cv. Varuna by interspecific hybridization. Continuous selection for higher fertility combined with a high degree of resistance to A. brassicaceae resulted in a fully fertile, productive and resistant genotype. The degree of resistance of this genotype was superior to all the commercial mustard varieties tested under high natural incidence of A. brassicaceae in the field over 3 consecutive years (Katiyar and Chamola, 1994).

Resistance to powdery mildew in okra

Immunity to powdery mildew was observed in biotypes of A. tetraphyllus, A. manihot, A. manihot subsp. manihot and A. moschatus. Nine virus resistant lines from the cross A. esculentus × A. manihot, one was highly resistant and two were moderately resistant to E. cichoracearum. The reactions of interspecific hybrids and their amphidiploids with cultivar Pusa Sawani revealed that the resistance was dominant in A. manihot and partially dominant in A. manihot subsp. manihot and A. tetraphyllus (Jambhale and Nerkar, 1992).

Creation of genetic variability

Wild relatives of vegetable crops are great reservoir of genetic variation and can prove useful in crop improvement. Generation of genic and cytoplasmic variability is very important for the improvement of any crop through breeding programs. Wild and weedy relatives of brassica crops are known to be reservoirs of genes that impart resistance to biotic and abiotic stress. Moreover, their cytoplasm can induce cytoplasmic male sterility (CMS) in crop brassicas, which is important for hybrid seed production in oilseed brassicas and heterosis in brassicas. The development of alloplasmic lines has also shown important agronomic traits like early flowering and dwarfhness in B. napus. Four species of genus Erucastrum have been utilized for intergeneric hybridization with crop brassicas. Erucastrum cardaminoides is a hardy plant that grows on volcanic soils and in rocky fields (Warwick et al. 2003). It possesses resistance to white rust, downy and powdery mildews and is tolerant to Alternaria blight. Hybrids between E. cardaminoides and two diploid crop brassicas, B. rapa (AA) and B. nigra (BB), have shown introgenomic affinity, indicating a possibility of introgression of genes. The intergeneric hybrid was also used as bridge species to transfer wild (E. cardaminoides) cytoplasm to B. napus and B. carinata. The new intergeneric hybrid and bridge cross hybrids produced in the present investigation have contributed towards increasing the genic and cytoplasmic variability and thus broadening the genetic base of Brassica crops (Mohanty et al., 2009).

Gene transfer for abiotic stresses

A phenotype is the result of the interaction of its genotype with environment. Different breeding strategies helps to develop genotypes that combine superiori in yield with tolerance to various abiotic stresses. High or low temperature, uneven photoperiod, moisture/ water stress, salinity, acidity, lack of nutrients and atmospheric and soil pollutants are the different kinds of abiotic stresses inhibiting the crop growth. Temperature tolerance is main objective in tomato, cucumber, melons and cole crops. Physiological processes like pollen viability, pollination, germination of pollen and its growth through style and fertilization are temperature sensitive. In tomato attempts were made to develop varieties which can set fruit at temperature above or below optimum by using wild species L. hirsutum f. glabratum (0-2°C). Varieties for low temperature tolerance are Cold Set, Pusa Sheetal, Ostenkinskiz and Punjab Tropics, Sparton Red, Avalanche etc. are for high temperature area. Potato is susceptible to frost and its resistant types are generally found in high altitudes of Peru, Bolivia, Northern Chile and Argentina. Back cross method has been adopted to develop frost resistant genotypes of potato by transferring genes from wide species such as S. microdentum, S.punea, S. vernei, S. andigena. Walter is a salt tolerant variety of tomato which was developed by using L. cheesmani as pollen parent. Capsicum flexuosum is one of the lesser-known species in the capsicum gene pool, native to south-eastern Paraguay, south-western Brazil and north-eastern Argentina. Simple tests confirmed that it can tolerate temperatures up to approximately -10°C for short periods. Frosts during the growing season are the major abiotic constraints to common bean (Phaseolus vulgaris) production and Phaseolus angustissimus was used to transfer resistant to both spring and fall frosts (Balasubramanian et al., 2003). A combination of pod, ovule and embryo culture protocols may be required to enable continued growth and development of the backcross embryo.
**Alteration in mode of reproduction**

Use of wild hybridization sometimes leads to alteration in mode of reproduction. The male sterility is most common alteration in mode of reproduction which results from interspecific hybridization. Cytoplasmic male sterility is the economic device for hybrid seed production. CMS has been discovered in cross between wild and cultivated species in potato, crucifers and carrot. Protoplast of *Lycopersicon esculentum* fused with protoplast of *Solanum aculeae* and *S. tuberosum* and male sterile plants were obtained (Rana, 2011). Cytoplasmic male sterile (CMS) plants were obtained by protoplast fusion between red cabbage and normal radish (Motege *et al.*, 2003). A new cytoplasmic male-sterility system was developed in the *B. juncea* variety Pusa Bold using the cytoplasmic background of the wild species *Diplotaxis sifolia* transferred by wide hybridization. The synthetic allopolyploid (*D. sifolia* × *B. juncea*: 2n = 56, DSDSAABB) was repeatedly backcrossed to *B. juncea* to achieve cytoplasmic substitution. The CMS plants resembled the cultivar in growth and morphology. The flowers had narrow sepals and petals and short, shrivelled anthers which failed to dehisce. The meiotic process was normal. The microspores degenerated at an early stage after tetrad formation. Female fertility in the CMS plants was as good as in the cultivar. Female transmission of sterility confirmed it to be cytoplasmically encoded (Rao, 1994). Hand emasculation is very difficult to produce hybrid seeds and lack of practically useful chemical agents for emasculation or inducing male sterility in carrot signifies the utmost importance of CMS for the development of highly adapted and uniform hybrid varieties of carrot. Two systems of cytoplasmic male sterility, namely the brown anther type (Sa) and the pateloid type (Sp) have been identified in carrot for utilization in breeding programs. A new CMS line from sterile cytoplasm of Wisconsin Wild has been released for hybrid seed production.

**Distant hybridization for quality traits**

Nutritional security of developing and underdeveloped countries heavily depends upon vegetables. Allied species of different vegetable crops such as wild, semi-wild and semi-cultivated carrying resistance to quality attributes are being exploited continuously for breeding purpose. In some crops wild species has been used to improve the quality of cultivated ones. For example carotenoid content in carrot and tomato, starch content in potato, total soluble solids in watermelon, muskmelon etc. has been improved through the use of their wild relatives. Wild species has been used to transfer dark green colour and excellent leaf texture in lettuce and bright red flesh in red peppers. Earliness to transfer dark green colour and excellent leaf texture in lettuce and bright red thin flesh in red peppers. Earliness to transfer dark green colour and excellent leaf texture in lettuce and bright red thin flesh in red peppers. Earliness to transfer dark green colour and excellent leaf texture in lettuce and bright red thin flesh in red peppers.

**Challenges using wide hybridization**

Wide crossing is an effective method of gene introgression from wild species for the improvement of cultivated crop species. Hybridizing adapted cultivars to alien species is often considered when the variation among adapted cultivars or landraces appears to be exhausted. Sometime a specific problem can be solved by obtaining specific genes from a wide cross. Wide crosses are difficult to make and even if accomplished, may produce progeny that is sterile or inviable. But this is very tedious task due to presence of pre fertilization or post fertilization barriers which hinders the process of gene transfer. These barriers restrict the use of wide hybridization in many crops. However wide hybridization in many crop species has been successfully utilized which showed cross compatibility with each other. Inter-specific crosses are easy to make as compared to inter-generic crosses due to wide differences in their gene pools. The barriers involved in wide hybridization and techniques to overcome these are as follows:

**Failure of zygote formation / cross incompatibility.**

Inability of the functional pollens of one species or genera to effect fertilization of the female gametones of another species or genera is referred to as cross incompatibility. It may be due to – 1. failure of fertilization, because the pollen may not germinate. 2. Pollen tube is unable to reach to embryo sac and hence sperms are not available for fertilization. 3. Pollen tube may burst in the style of another species eg. *Datura*. 4. The style of the female parent may be longer than the usual length of the pollen tube growth therefore the pollen does not reach the embryo sac. eg. *Zea mays* and *Tripsacum sp.* 5. Pollen tubes of polyploidy species are usually thicker than those of diploid species. 6. When a diploid is used as female and a polyploidy as male, the polyploidy pollen tube grows at a slower rate in the diploid style than it would be in a polyploid style. These barriers are known as pre-fertilization barriers. Techniques to make wide crosses successful in such cases involve removal or scarification of stigma, using short styled parent as female and use of diploid species as the male parent.

**Failure of zygote Development / Hybrid inviability.**

The inability of a hybrid zygote to grow into a normal embryo under the usual conditions of development is referred to as hybrid inviability. This may be due to presence of lethal genes in some species, which causes death of the interspecific hybrid zygote during early embryonic development. eg. *Aegilops umbellulata* carries a lethal gene with 3 alleles against diploid wheats.

The genetic imbalance or dishormony between the two parental species may also cause the death of embryos. eg. *Brassica – B.napus × B.oleracea*. In some cases of distant hybridization, chromosomes are gradually eliminated from the zygote. This generally does not prevent embryo development, but the resulting embryo and the F1 plants obtained from such crosses are not true interspecific hybrids.
since they do not have the two parental genomes in full. Generally, chromosomes from one are successively eliminated due to mitotic irregularities. This technique has been successfully utilised in some crops for production of double haploids eg. production of inbreds in onion (Alan, 2003). Embryo development may be blocked by an incompatibility between cytoplasm of the species used as female and the genome of the species used as male. Such an interaction, more generally, leads to hybrid weakness and male sterility in the hybrids or may sometimes leads to failure of embryo developments. Seeds from a large number of distant crosses are not fully developed and are shrunken due to poorly developed endosperm. Such seeds show poor germination and may often fail to germinate. When the endosperm development is poor or is blocked, the condition is generally known as endosperm abortion. eg. 1. *Triticum x Secale – Triticate*. In this case the endosperm aborts at a much later stage so that a small frequency of viable seed is obtained. 2. *Hordium bulbosum × H. vulgare*, the endosperm aborts at an early stage so that viable seeds are not produced. In case of endosperm abortion –embryo rescue culture is practiced (Choudhary, 2005).

**Failure of Hybrid seedling development / Hybrid sterility**

Hybrid sterility refers to the inability of a hybrid to produce viable off spring. The main cause of hybrid sterility is lack of structural homology between the chromosomes of two species. Some distant hybrids die during seedling development or even after initiation of flowering. The mechanisms involved in the failure of seedling development most likely involve complementary lethal genes. eg. 1. In cotton, certain interspecific hybrids appear normal, but die in various stages of seedling growth; some plants die at flowering. 2. Interspecific and intergeneric F₁ hybrids of wheat show both chlorosis and necrosis (Singh, 2005).

**Strategies for making wide hybridization successful**

**Choice of parents**

Genetic differences exist among parents in a species for cross compatibility. More compatible parents should be selected for use in wide crosses.

**Pollinating sufficiently large no. of flowers**

The success of seed set is generally very low in the wide crosses. Hence large number of crosses should be made to obtain crossed seeds.

**Reciprocal crosses**

It is better to attempt reciprocal crosses when distant crosses are not successful. eg.: *Phaseolus aureus* and *p.mungo* are crossable only when *P. aureus* in used as female and *P. mungo* as male.

**Determine the barrier and then take measures to overcome it**

In longer style species cut the style, use more than one strain of each species for lethal genes, autopolyploidy (*B.oleracea x B. compestris*), manipulation of ploidy level can be done when two species of a cross differ in chromosome number, it is necessary to manipulate their ploidy. Ploidy levels can be manipulated as a. Direct crossing by using higher ploidy species as female parent. b. Chromosome no. of the wild species or of the interspecies hybrid (F₁) may be doubled to overcome sterility of the hybrid.

**Bridge crosses**

Some times, two species say ‘A’ and ‘C’ do not cross directly. In such case a third species say ‘B’ which can cross with both ‘A’ and ‘C’ is chosen as a bridge species. First ‘B’ is crosses with ‘C’ and then the amphidiploid is crossed with ‘A’. Bush habit and multiple disease resistance has been transferred from *Cucurbita pepo* to *C. moschata* and *C. maxima* using *C. lundelliana* as a bridging species. *Capsicum chinense* performed as a good bridge species between *C. annuum* and *C. Baccatum* (Manzur et al., 2015)

**Use of pollen mixtures**

Cross incompatibility results due to unfavourable interaction between the protein of pistil and pollen which inhibits normal germination and growth of pollen tube. This problem can be overcome by using the mixture of pollen from compatible (self) and incompatible parents.

**Manipulation of pistil**

In some cases, pollen tube is short and style is very long, due to species difference. Thus pollen tube cannot reach ovule to effect fertilization. In such situation either reciprocal cross should be made or the style should be cut to normal size before pollination. This technique is successful in maize – *Tripsacum* crosses, where maize style remains receptive even after cutting.

**Use of growth regulation**

Sometimes, the pollen tube growth is very slow that the eggcell dies or the flower aborts before the male gametes reach the ovary. In such cases, growth regulators should be used to accelerate the pollen tube growth or to prolong the viability of the pistil. Use of growth regulators such as IAA, NAA, 2, 4-D and GA₃ etc. are promising in some wide crosses.

**Large number of crosses**

The success of seed set is generally very low in wide crosses. Hence, large no. of crosses should be made to obtain crossed seeds.

**Protoplast fusion**

The wide crosses can be obtained through protoplast fusion, when it is not possible to produce such crosses through sexual fusion. Interspecific somatic hybrid plants obtained from crossing eggplant (*Solanum melongena*) with *Solanum torvum* showed resistant to Verticillium wilt in brinjal (Guri and Sink, 1988).

**Embryo culture**

This technique is being used widely to obtain viable
Table 1: Practical Achievements using wide hybridization.

| Crop                  | Attribute                        | Resistant Source                                                                 | Resistant Varieties                                                                 |
|-----------------------|----------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Tomato                | Leaf Curl Virus                  | L. hirsutum f. glabratum, L. peruvianum, L. pimpinellifolium, L. glandulosum      | H-36, Bilahi-1, Bilahi-2, Hissar Gaurav, Hissar Anmol (H-24) Kalloo and Banerjee (2006) |
|                       | Bacterial Wilt                   | L. pimpinellifolium                                                              | Arka Abhijit, Shakti, Arka Alok, Arka Shresha, Megha, Sonali                        |
|                       | Root Knot Nematode               | L. peruvianum                                                                    | Hissar Lalit, Pusa 120, Nimatex, Atkinson, Arka Vardan                              |
|                       | Temperature Stress               | L. hirsutum and L. chilense                                                     | Cold set, Pusa Sheetal (for low temperature), Pusa Hybrid-1 (for high temperature), Pusa Sadabahar (for both high and low temperature) |
| Okra                  | Salt tolerance                   | L. peruvianum, L. cheesmani sp. minocL. pimpinellifolium                         | Calmer, Calimax-84, Tom Thumb                                                     |
|                       | Yellow Vein Mosaic Virus         | Ablemoschus manihot ssp manihotA. tetraphyllus                                   | Parbhani Kranti, Arka Anamika, Arka Abhay, Pusa A4, VRO-6                          |
| Brinjal               | Bacterial Wilt                   | Solanum torvum, S. xanthocarpum, S. nigrum, S. sisymbriifolium, S. melongena    | Panjab Barsati, Arka Nidhi, Arka Keshav, Arka Neelkanth, Pusa Purple Cluster, Long Green, Pant Rituraj |
|                       | Phomopsis blight                 | Solanum torvum, S. xanthocarpum, S. nigrum, S. sisymbriifolium, S. gilo, S. indicum | Florida market, Florida beauty, Pusa Bhairav, Pusa Purple Cluster, Pant Samrat                                                        |
| Muskmelon             | Downey mildew                    | C. callosus                                                                      | Florida, Seminol, Edisto, Homegarden                                               |
|                       | Fusarium wilt                    | C. melo var. reticulatus, C. melo var inodorus, C. melo var flexuosus            | Spartan Rock, Delicious 51, Harela                                                   |
| Potato                | Increased protein content, frost and disease resistance and capacity to tuberise under short day conditions and high temperature | Solanum acaule, S. ajanhuri, S. andigena, S. brevidens, S. bulbocastanum, S. chacoense, S. demissum | Croisement, Herkol, Perfect, Atzimba (late Blight); Desiree, Lauvakar (heat tolerant), Kufri Sheetman, Kufri Deva (frost resistant); Kufri Chandramukhi, Kufri Snduri (Protein content) |
| French Bean           | Fusarium Yellow, Angular leaf spot, Anthracnose | Phaseolus acutifolius, P. coccineus                                               | Pant Anupama, Tenderette, Pintado Early Gallatin, Way Michelite                    |
interspecific or intergeneric hybrids. This is used when hybrid zygote is unable to develop. This technique has been successfully used in, *Lycopersicon, Cucurbita, Capsicum* (Manzur et al., 2015), *Cucumis* (Xiaqing et al., 2015) etc.

**Grafting**

Grafting of interspecific hybrid on to the cultivated species helps in making the cross successful. As an effective tool for management of root-knot nematodes (*Meloidogyne* spp.) and other soil-borne diseases (Guan et al., 2012; Louws et al., 2010), grafting has been successfully used in production of solanaceous and cucurbitaceous vegetables such as tomato, eggplant (*Solanum melongena*), pepper (*Capsicum annuum*), watermelon (*Citrus lanatus*), melon (*Cucumis melo*) and cucumber (*Cucumis sativus*) in both protected and open-field production systems (Lee et al., 2010). Beyond disease resistance, efficiency of nutrient and water use may increase in grafted vegetable plants, an effect often ascribed to the vigorous root systems of rootstocks (Albacete et al., 2015).

**CONCLUSION**

Crop relatives have been used for decades for breeding, in particular to transfer genes of resistance or tolerance to pests, diseases or abiotic stress to the cultivated species. Introgression breeding has been extensively used in the genetic improvement of some of the most important vegetable crops, like potato, tomato, cucurbits etc. However, breeding programmes in the other economically important common crops have made little use of related species for breeding. Use of distant hybridization for the improvement of vegetable crops is still limited to few crops because of low success rate. This limitation has been mainly due to the presence of different pre-zygotic barriers which avoid fertilization (*e.g.* pollen-pistil incompatibilities) and/or post-zygotic barriers, which prevent the achievement of fertile hybrids. So wide hybridization accompanied by some specialized techniques like grafting, bridge crosses and embryo culture is a useful tool for successful gene introgression in vegetable crops.

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