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New Developments in Breeding of Flower Crops

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India has an amazing wealth of flower crops and domestic flower requirement exists from time immemorial for worshipping god, decorations for social functions as well as for temple. Apart from appreciating flowers for their aesthetic beauty, its value as auspicious item is the major criterion in cultivation of flower crops. Flowering plants are also integral part of gardens and landscape, making their breeding program not just crop oriented but also utility oriented. Since the past two decades, export oriented floriculture has gained significant importance. The first phase of cut flower production started during the 8th Five Year Plan (1992-97) when export oriented floriculture was declared as extreme focus area and was encouraged as sunrise industry. This export business of floriculture invaded in to the country with a sole aim of capturing the international markets. Initial days of the industry saw everything as import–export business; with technical assistance, planting materials, green house equipments starting from nut and bolt to sheet everything was imported and only finished flowers were to be exported. These ventures of floriculture business that depended on imported material and technology could not last longer and end of the 20th century as well as the beginning of the new millennium saw wilting of many business units. That was the 2nd phase when failures of polyhouse cultivation totally dependent on foreign technology was realised. Second phase of floriculture can be considered as crucial period of problems and hard lessons learnt in terms of variety, polyhouse structures, necessity of good logistics etc. The 3rd phase which can be considered for the past one decade, saw the regaining of the industry with the modified cost effective technology of naturally ventilated polyhouses and protected structures adaptive to local agro climatic conditions and new technical persons and skilled persons emerging out locally. And in the past one decade the whole industry has taken a surprising turn with new domestic market emerging out with internal demand matching and sometimes even surpassing that of export demand.

It is now time to start the 4th phase, and emerge out with Brand-India tag. Instead of supplying what is already available in the global market, its time to focus on our own strengths and market our products, our varieties and export them. In addition, with the raising internal demand, it is time to cater to the domestic market. And this time breeders have to play a major role with new varieties. It is very essential that we have to emerge out with our own varieties as India has opened up and started protecting the rights of breeders. And already rose varieties have got registered by the

foreign breeders that means royalty has to be paid to the breeder even if the cultivati
is for domestic market.

Introducing New and Native

The dynamic floriculture industry demands new product, new colour, shape, for
size; anything distinct has the greater demand. Enhancing the palette of ornamer
plants necessitates identification of the new varieties and species that have survive
niche remote areas and homestead gardens. Domesticating them is a major area
needs focusing in floriculture breeding. Identification of native species from diver
rich regions and protecting them and providing the benefits to the native pe
should be taken up in a large scale. It is important to involve industry into this so
commercialization of the identified species and varieties can be taken up at the ea
and with this we can also catch niche markets and open new market oriented su
chains. These native varieties and species will also help the breeders to expan
variability, and to introduce new characters into the gene pool.

Breeding for Adverse Climate and Poor Soil

Flowers have unique advantage as they are mostly non-consumed group. Th
growing international interest in the commercial use of native species. Iden
species and genotypes that can tolerate environmental stresses, that can
under poor soil, less water, warm and cold extremes should be an area of p
Chrysanthemums are moderately tolerant to salinity, roses come up well in s
is slightly acidic (6-6.6 pH) and it is important to identify range of crops and
varieties for adverse climate and soil conditions. Marker genes that can work
species, as indicators for plant stress response needs identification. The imp
of green areas is increasingly considered for the restoration of polluted
ecosystems. Phytoremediation appears to be a promising technique for soil me
up especially where the area has little or no alternative uses. Ornamental pl
be used for this purpose in urban design, where both environmental and ae
solutions are needed. *Alyssum*, *Pelargonium* and *Helianthus* have been report
the most suitable for phytoremidiation (Larcher *et al.*, 2012). Breeding the va
different crops species that has the better phytoremidiation property will be a
to be explored.

Breeding for Fragrance

Besides aesthetic beauty, flowers are also known for their fragrances. There
flowering species such as jasmine, champa, tuberose and rose that are w
for their fragrances. Investigation done on the effects of flower fragrances
(*Lilium*), violet (*Matthiola incana*), gardenia (*Gardenia jasminoides*) and lem
limon) on human psycho-physiological responses have indicated their effe
reducing stress, fatigues and anxiety (Li Xia *et al.*, 2012). Particularly in ros
has wide range and it is important to have a focus on introducing this chara
to commercial varieties. Understanding floral scent composition will help
distinct novel types. Breeding program at ICAR-IIHR has resulted in i
of Arka Parimala and Arka Sukanya, two fragrant varieties that differ in
are distinct. Besides these two released varieties, we have series of advanc
lines in fragrant rose category, each one differing from the other in thei

7-4, IIHR P-7, IIHRP-30 and IIHRP-36 are some of the advanced fragrant breeding lines and scent ranges from mint to musk. India has historic records of rose flowers being used in extraction of attar, otto, rose oil and for scenting tea. All these rose extracts are in great demand by cosmetics industries. Linking with aromatic industry and aroma therapy will have great potential for commercial cultivation of aromatic flower varieties.

Breeding for Alternate Uses of Flower Crops

Flower crop breeding need not be limited for its aesthetic value. Another area of interest would be developing varieties for alternate usage. At present, there is an increasing demand of food species with high contents in health promoting compounds and varieties with improved nutritional quality are of interest. For instance, marigold (*Tagetes sps*) flowers are a very rich source of carotenoids for application in the food and feed industry. Commercially, carotenoid pigment in marigold flowers are used in poultry feed to provide yellow colour to the skin of broilers and yolks of layers (Liu et al. 2011). The principal carotenoid pigment of marigold flower is xanthophyll consisting of zeaxanthin and lutein esters which have been reported to be beneficial to several aspects of human health. Xanthophylls offer an alternative to synthetic colours and used as natural food colorant and nutrient supplement. Luteins are of significant importance to pharmaceutical industry as they are known to have series of beneficial effects particularly for eye sight. It is important to identify lines with varying fractions of carotenoid components so that breeding program can involve the right lines with good combining ability. In a hybridisation program it is important to realize that lines with good combining ability of these carotenoid fractions are important rather than selecting the lines with higher mean values of these fractions. Arka Agni released from ICAR-IIHR has 1.4gm of total carotenoid, 1.5mg of zea xanthin and 1.1gm of lutein per100 gm of dry petals.

Natural pigment is in great demand by food industry particularly red colour and anthocyanins are the candidates for this. Anthocyanins are water sluble and vacuolar pigments. Breeding program at ICAR-IIHR has resulted in IIHRP-7 that is rich in anthocyanin content (1.5g/100 g dry weight of petals). A large number of products such as wines, juice, jams and soft drinks are coloured by anthocyanins. Using anthocyanin of rose has added advantage of flavor in addition to the colour. Rose fruits are known to be rich in ascorbic acid and are used as food and food additives. This is another area where breeding program need to be initiated.

Utilisation of Gametophytic Generation in Breeding Program

Many of the flower crops have inherent problems of seed germination. Several flower crops are perennial and breeding program takes long time. Conventional breeding methods are time consuming and laborious and concentrate only on the sporophytic generation. As an alternative, the gametophytic phase holds promise for breeding due to its haploid state wherein recessive alleles remains unmasked. Consequently possibility of selecting desirable allelic combinations under gametophytic selection is expected to be higher than in sporophytic selection (Tejaswini and Ganeshiah, 2001). Probability of selecting complex allelic combinations in gametophytic generation is high as the population size available for screening and selection in gametophytic generation far exceeds to that in sporophytic generation. There are immense possibilities of using

gametophytic generation as an efficient strategy in plant breeding methods (Tejaswini, 2003). IIHR has released three cut flower varieties, Arka Swadesh, Arka Ivory and Arka pride utilizing gamtophytic selection, an alternative strategy of breeding. The possibility of developing an alternate breeding technique, exploiting hidden potential of gametophytic generation needs to be explored in different flowering crops.

Mutation Breeding for Flowering Crops

The induction of mutations in the plant genome is an alternative method for breeding besides selection, hybridization and transgenesis. This method can generate variation very quickly and decrease the time of the breeding process. Mutation is a major breeding procedure followed in ornamental crops for varietal development. Bud sports and natural mutants are selected and established as separate varieties, making mutation as a major approach of breeding ornamental crops. Induced mutation using X rays, gamma rays, and chemical mutagens is on raise creating variability and novelty. Target mutagenesis of genes associated with preferred traits has been advancing continuously, and a precise technique applicable to genome modification of plants has been introduced (Lee et *al.*, 2016).

Interspecific Hybridization and Novelty

In ornamental plants, interspecific hybridization has successfully been used to produce novel cultivars with useful traits of both parents and to incorporate desirable traits of one species to another. Advanced breeding techniques like embryo rescue, polyploidization, protoplast fusion and molecular cytogenetic methods are used to produce and characterize interspecific hybrids in various taxonomic groups. Most of the ornamental plants are polypolid because of constant interspecific hybridization followed with doubling of chromosomes. 'Arka Tejas' is an interspecific hybrid of *Dianthus* released by ICAR-IIHR. It is an interspecific hybrid between carnation *(D. caryophyllus)* and Pinks (*D. chinensis*) and is a new form of flowering plant ideal for pots.

Male Sterility in Flower Crops

Strategies and objectives in flower crop breeding remains entirely different from majority of other crops with the focus on end product as flowers and not fruit or seed as the case in most of the food crops. Flowers that can remain without senescence on plant for long duration and with longer shelf-life after harvest are the priority characters aimed in breeding of flower crops. Senescence of flowers is mainly attributed to ethylene, presence of which leads to shortening flower life and loss of bright colour. Flower senescence is regulated by increased amount of ethylene production following pollination and fertilization. With no functional pollen, male sterile flowers in turn are expected to have longer life. Pollen production as well as fertilization leading to production of fruit and seeds is essential for food crops, including fruits and vegetables. On the contrary, fruit and seed are not required for a flower crop, and production of pollen is undesired investment for flower crop. Thus, male sterile line is advantageous and desired in flower crops not just as a parent for production of hybrid seeds; but as a variety itself provided the flowers are attractive. Male sterility will also be useful in case of transgenic plants as mechanism to inhibit transmission of transgene flow to

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species Arka Agni, Arka Bangara and Arka Bangara-2 are the three male sterile varieties of marigold released by ICAR-IIHR.

Biotechnological Approaches in Flower Breeding

Tissue Culture Besides utilizing tissue culture for mass propagation, it is also used as a tool for creating variability and screening. Sectorial mutants are very common in flowering crops. *In vitro* approach can be used for purification and regeneration from a mutated sector. Subjecting the minimum unit of explant to mutagen can be achieved through induction of mutation under *in vitro* conditions of tissue culture where diplontic selection pressure is avoided and the opportunity for the mutated cell to survive gets increased. Carnation variety 'Arka Flame' released by ICAR-IIHR is a result of *in vitro* mutagenesis approach through selection and purification from a sectorial mutant IIHRS-1. With the natural diversity being eroded by lots of human activities, it is important to save the gene pool. In ornamentals, diversity itself is of aesthetic value and *in vitro* conservation approach through tissue culture will help to save more number of species.

Molecular Markers Marker assisted selection is another approach gaining importance in flower crop breeding. Diversity studies are mainly being done based on morphological characters. Classification and grouping of germplasm based on molecular characterisation will be having added advantage as that will reveal genetic background of the genotypes which in turn facilitates for precise classification and selecting the right genotype for breeding program. In the era of breeder's right taking the priority, it is important to be prepared with appropriate molecular markers so that we will be able to distinguish individual genotypes based on their genetic background. Primers with high power of discrimination need to be identified in each species for establishing the distinctness of varieties and supporting the claim of breeder's rights. In morphological testing, a single character difference is considered sufficient to assign the status of distinctness for a genotype. In a similar way, there is a necessity for fixing up critical threshold value of either allele differences or measures of coefficient for considering the uniformity criterion and to distinguish the varieties.

Genomics Understanding the gene sequences is of interest not just for academic curiosity but also for application in creating new variety. Not much work has been done in flower crops. Rose is the one flower crop where the work is in progress. Rose represents an original model for studying some ornamental traits of economic interest such as recurrent blooming, flower morphogeneis, scent production and emission that cannot be addressed in other model plant species such as *Arabidiopsis* (Foucher et al., 2015). Most of the genomic studies in rose has been done through transciptomic approaches. Next generation sequencing technologies were used to discover new genes and study *in silico* their expression (Dubois et al., 2012; Kim et al., 2012). With the completion of rose genome information, markers associated with desired locus can be rapidly obtained and used for marker associated selection for adult traits in seedling stage itself, accelerating the breeding program.

Development of Transgenics Molecular breeding utilizing genetic engineering techniques has liberated breeders from species specific gene-pool constraint. For successful transgenic development, it is necessary to isolate relevant genes, establish transformation systems, optimize expression of transgenes and obtain regulatory permission for both production and consumption. An efficient

transformation system has been developed for rose and carnation. Transgenics have been produced in rose and carnation whose flowers accumulated delphinidin based anthocyanins and an altered colour. Through careful choice of host cultivar and optimization of the expression of transgenes, it has been possible to obtain transgenic plants with flowers exhibiting an attractive colour range of blue/violet hitherto unavailable in rose and carnation (Tanaka and Chandler, 2009)

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