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# Role of Biotechnological Interventions in Improving the Traits of Flowering Ornamentals

*Waseem Shahri*
*Department of Botany, Government College for Women, Cluster University, Jawahar Nagar, Srinagar 19000, Kashmir, India*

**ABSTRACT**
Improving the floricultural traits in ornamentals is of great value in floriculture and landscaping. Conventional methods have been and are being still used for improving the floricultural traits like vase life or floral longevity, ethylene sensitivity and visible floral morphological features, etc. in ornamentals by postharvest application of ethylene antagonists, plant growth regulators, sugar sources, protein synthesis inhibitors and antimicrobial compounds, etc. However, biotechnology offers a promising approach to improving the desirable attributes in flowering ornamentals like flower color, fragrance, longevity, ethylene insensitivity, disease resistance, etc. In the present review, the biotechnological interventions in enhancing the flower fragrance, flower color and flower longevity/vase life have been discussed and a number of suitable examples related to the improvement of these traits in various ornamentals have been provided. The mini-review intends to present a comprehensive update of the available literature regarding the improvement of these traits in flowering ornamentals involving the non-conventional biotechnological approach.

**KEYWORDS**
Biotechnology, flower color, fragrance, longevity, transgenics, ornamentals, floriculture



## INTRODUCTION

Floriculture or flower farming, one of the important horticultural disciplines, primarily focuses on various parameters related to ornamentals that include their propagation, cultivation, harvesting, as well as postharvest processing. Efforts have been made and are being made to improve the floral attributes so as to make them more market-oriented. The research leading to the improvement in the attributes of these ornamentals is being conducted at different levels-preharvest level, harvest and postharvest level. The preharvest level research parameters include the quality of the plant material (seed, bulb, rhizome, etc.), appropriate growing conditions (soil requirements, fertilizer application, water requirements, light conditions and temperature etc.) and protection from diseases and pests. Appropriate time of harvest, the right method and the right stage of harvest are the primary factors influencing the harvest stage. The postharvest level factors that influence the attributes of ornamentals include proper transportation and storage, use of chemical preservatives and growth regulators as pulse or spray treatments, maintenance of sugar supply, use of antimicrobial agents in vase solutions, use of ethylene antagonists and optimum ranges of temperature and relative humidity, etc. A number of floral

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attributes like size, longevity and quality have been improved to a great extent by research at pre-harvest as well as postharvest level. Moreover, the intervention of biotechnology or genetic engineering has offered a promising approach for developing new ornamentals with improved floral attributes as well as producing ornamentals with novel traits. Altered flower colour, enhanced fragrance, disease resistance, ethylene in-sensitivity (in ethylene-sensitive flowers) and early blooming are some of the important attributes that have been targeted using biotechnological interventions[1-4]. The present review intends to provide comprehensive information about the role of biotechnology in improving and modifying the attributes of ornamentals with the purpose to enhance their commercial value.

**Flower fragrance:** The flower fragrance has been attributed to the biosynthesis of many volatile compounds like terpenoids, benzenoids, phenylpropanoid and other Sulphur or Nitrogen-containing compounds[5]. Floral fragrance or scent production in ornamentals offers many advantages like a signal for pollinators, attraction for predators of herbivores and repulsion of herbivores, etc[5-7]. A number of ornamentals have been genetically modified to enhance scent production. Some of the notable examples were listed in Table 1.

From Table 1, it is clear that scent production has been enhanced in the ornamentals by using two approaches i.e. either by inducing the production of volatile compounds like Benzyl acetate and S-linalool or by regulating the expression of the *F3'H* gene (downregulation in Carnation) or *PAP1* gene (Overexpression in Rose). Here, it deserves mention that the *AtPAP1* gene is responsible for flower color modification as well as for enhancing the fragrance.

**Flower color:** Another important attribute of ornamentals is the floral display in the form of various colors which has been attributed to the occurrence of different plant pigments in the floral organs. These pigments include anthocyanins, chlorophylls, carotenoids, betalains, etc. These pigments are known to play important roles like attraction to pollinators, light capturing for photosynthesis and protection from UV radiation besides determining the ornamental value of the plants[12]. Many ornamentals have been genetically engineered to produce flowers with novel colors or enhanced colors. Some of the notable examples were listed in Table 2.

A number of flowers with novel or enhanced flower colors have been obtained using the biotechnological approach (Table 2) wherein the genes like *DFR gene*, *F3'H* genes, *F3'5'H* genes and *PAP1* gene have been introduced to host ornamentals and made to express and produce the novel phenotype. Moreover, the silencing or down regulation of genes like the CHS gene (Chalcone synthase), ANS gene, *F3'5'H* genes and the overexpression of the *PAP1* gene and CrtW gene have been found to enhance or modify the flower color in many ornamentals.

**Vase life/shelf life:** Another important parameter that determines the postharvest quality of ornamentals is their vase life or shelf life. Flower longevity or vase life determines how long a flower or a spike or scape remains in fresh condition after being detached from the mother plant, particularly in the case of cut flowers. A number of preharvest and postharvest treatments are known to enhance the vase life or shelf life of ornaments by conventional use of Plant Growth Regulators (PGRs) and vase solutions containing

Table 1: Genetic modification in ornamentals for flower fragrance

| Plant | Gene | Source | References |
|---|---|---|---|
| Carnation and lisianthus | *LIS* gene that codes S-linalool synthase | *Clarkia breweri* | Zaccai *et al.*[8] |
| Carnation | Downregulation of the *F3H* gene | Carnation | Zuker *et al.*[9] |
| Lisianthus | Benzyl alcohol acetyl transferase (BEAT) for the production of benzyl acetate | *Clarkia breweri* | Aranovich *et al.*[10] |
| *Rosa hybrida* | Overexpression of the *AtPAP1* gene | *Arabidopsis thaliana* | Zvi *et al.*[11] |

Table 2: Genetic modification in ornamentals for flower color

| Plant | Gene | Source | Altered flower color | Reference number |
|---|---|---|---|---|
| *Petunia* (deficient in *F3'5'H* and *F3'H*) | *DFR* gene | Maize | Orange | Meyer *et al.*[13] and Meyer *et al.*[14] Forkmann *et al.*[15] |
| *Chrysanthemum* (Pink) | Expressing sense or antisense copies of the *Chs* gene encoding chalcone synthase | - | White or light pink | Courtney-Gutterson *et al.*[16] |
| Carnation (White) | *F3'5'H* and *DFR* gene | *Petunia* | Blue (FLORIGEN) E®Moondust™) | Lou *et al.*[17] |
| Carnation (white) | *F3'5'H* and *DFR* gene | *Viola* and *Petunia*, respectively | Dark violet FLORIGENE® Moonshadow™ | Mol *et al.*[18] |
| *Arabidopsis* and Tobacco | Overexpression of *PAP1* | *Arabidopsis AtMYB75*, (*PAP1* transcription factor) | Flowers with enhanced pigmentation | Borevitz *et al.*[19] |
| Carnation | Antisense gene construct for *F3'H* gene | Carnation | White | Zuker *et al.*[9] |
| Petunia | Down regulation of *F3'H* gene (petunia) and over expression of rose *DFR* gene | *Rosa* | Red | Tsuda *et al.*[20] |
| Rose | *F3'5'H* gene | *Viola* | Blue rose | Katsumoto *et al.*[21] |
| *Torenia* | Anthocyanin biosynthesis genes (by employing RNAi) | *Torenia* | White | Nakamura *et al.*[22] |
| *Torenia* (Blue) | Down regulation of *F3'5'H* and *F3'H* genes and over expression of Pelargonium *DFR* gene | *Pelargonium* | Pink | Nakatsuka *et al.*[23] |
| Tobacco | Down regulation of *F3'H* gene and flavonol synthase gene and overexpression of gerbera *DFR* gene | *Gerbera* | Red | Nakatsuka *et al.*[23] |
| *Lotus japonica* | Overexpression of *CrtW* gene | *Lotus japonica* | Deep yellow to orange | Suzuki *et al.*[24] |
| *Gentiana* | Suppression of the *F3'5'H* gene | *Gentiana* | Magenta | Nakatsuka *et al.*[25] |
| Gentian | Silencing of *CHS* and *ANS* genes | Gentian | White and pale blue, respectively | Nakatsuka *et al.*[25] and Yoshida *et al.*[26] |
| Gentian | Downregulating the *F3'5'H* gene and the *5,3'-AT* gene (encoding anthocyanin) | Gentian | Pink | Nakatsuka *et al.*[25] |
| *Chrysanthemum* | Expressing *F3'5'H* gene under rose CHS promoter | - | Blue | Nakatsuka *et al.*[27] |
| *Chrysanthemum* | Suppression of *CmCCD4a* (Carotenoid cleavage dioxygenase) gene | *Chrysanthemum* | Yellow (Yellow Jimba) | Ohmiya *et al.*[28] and Ohmiya *et al.*[29] |
| *Lilium* | Ph*F3'5'H* gene | *Phalaenopsis* | Purple | Azadi *et al.*[30] |
| *Cyclamen persicum* (Purple) | Suppression of the *F3'5'H* gene | *Cyclamen* | Red/Pink | Boase *et al.*[31] |
| *Chrysanthemum* | Suppression of *CmF3'H* gene | *Chrysanthemum* | Bright red | He *et al.*[32] |

sugars, sugar alcohols, biocides, ethylene antagonists and other chemicals[33,34]. However, genetic engineering has also been employed to produce ornamentals with enhanced shelf life/vase life. Some of the notable examples were listed in Table 3.

Table 3: Genetic modification in ornamentals for enhanced vase life

| Plant | Gene | Source | References |
|---|---|---|---|
| Carnation | Silencing the ACO gene | - | Savin *et al.*[35] |
| Carnation | *etr1-1* gene | *Arabidopsis* | Bovy *et al.*[36] |
| *Petunia* | Transformation of *etr1-1* gene | *Arabidopsis* | Gubrium *et al.*[37] |
| *Chrysanthemum* | | | Ma *et al.*[38] |
| Carnation | *ACO* gene and *ACS* gene | Carnation and apple | Inokuma *et al.*[39] |
| *Oncidium* | Mutating ethylene receptor gene | - | Raffeiner *et al.*[40] |
| *Odontoglossum* | Mutating ethylene receptor gene | - | Raffeiner *et al.*[40] |

Another feature added to the cap of ornamental biotechnology is the development of fluorescent flowers in Torenia by using a yellowish-green fluorescent gene-*CpYGFP* from the marine plankton *Chiridius poppei*[41]. These fluorescent ornamentals serve the dual purpose-one being the enhancement of the ornamental value of the plant and the other being used for the analysis of fluorescent transgenic plants spatiotemporally in a non-destructive manner.

## CONCLUSION

In conclusion, biotechnology involving the genetic engineering approach has not only provided a significant contribution to modifying or improving the existing traits of flowering ornamentals but has led to the production of ornamentals with novel traits. These modifications in ornamentals have been proven to be a successful venture from scientific as well as commercial points of view. As far as the future perspective of ornamental horticulture is concerned, biotechnology has an important role to play which involves the extension of the existing biotechnological strategies/approaches to other related ornamentals and to promote research in more areas related to flowering ornamentals.

## SIGNIFICANCE STATEMENT

Biotechnology offers a promising approach to improve the traits of the ornamentals when compared to traditional methods of ornamental plant improvement. Using the biotechnological approach, many milestones have been achieved while dealing with ornamentals like enhancement of vase life or flower longevity, enhancing the floral fragrance/scent, modifying the flower color or producing flowers with novel colors and reducing sensitivity to ethylene, etc. The purpose of the mini-review was to present an update on the improvement of some selected traits in flowering ornamentals using the biotechnological approach. Many examples of genetic modifications in ornamentals have been provided in the review so as to comprehend the importance of biotechnology in ornamental horticulture.

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