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Research review paper

Current status and biotechnological advances in genetic engineering of ornamental plants

Pejman Azadi [a,*], Hedayat Bagheri [b], Ayoub Molaahmad Nalousi [c], Farzad Nazari [d], Stephen F. Chandler [e]

[a] Department of Genetic Engineering, Agricultural Biotechnology Research Institute of Iran (ABRII), Agricultural Research, Education and Extension Organization (AREEO), Karaj, Iran
[b] Department of Plant Biotechnology, Faculty of Agriculture Science, Buali Sina University, Hamedan, Iran
[c] Department of Horticultural Science, Faculty of Agriculture Science, University of Guilan, Rasht, Iran
[d] Department of Horticultural Science, College of Agriculture, University of Kurdistan, Sanandaj, Iran
[e] School of Applied Sciences, RMIT University, Bundoora, Vic, Australia

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ABSTRACT

Cut flower markets are developing in many countries as the international demand for cut flowers is rapidly growing. Developing new varieties with modified characteristics is an important aim in floriculture. Production of transgenic ornamental plants can shorten the time required in the conventional breeding of a cultivar. Biotechnology tools in combination with conventional breeding methods have been used by cut flower breeders to change flower color, plant architecture, post-harvest traits, and disease resistance. In this review, we describe advances in genetic engineering that have led to the development of new cut flower varieties.

Contents

Abbreviations: A. t, *Agrobacterium tumefaciens*; *A. tumefaciens*, *Agrobacterium tumefaciens*; ACC, 1-aminocyclopropane-1-carboxylate; ANS, Anthocyanidin synthase; *EAT*, Benzyl alcohol acetyltransferase; *BYMV-CP*, Bean yellow mosaic virus coat protein gene; *CAB*, Chlorophyll a/b-binding protein; *CAG1*, A chrysanthemum-AGAMOUS homolog; CaMV, Cauliflower mosaic virus; *CaXMT1*, *CaMXMT1* and *CaDXMT1*, *N*-methyltransferase genes; CHI, Chalcone isomerase; *Chi*II, *Rice chitinase* gene; CHS, Chalcone synthase; *CmCCD4a*, The gene encoding a carotenoid cleavage dioxygenase which express specifically in white petals; *CmETR1/H69A*, Ethylene receptor genes from melon; *CMV CP I*, Cucumber mosaic virus subgroup I coat protein; *CMV CP II*, Cucumber mosaic virus subgroup II coat protein; CMV, Cucumber mosaic virus; *CP*, Coat protein gene; CPase, Cysteine proteinase; DFR, Dihydroflavonol 4-reductase; *DgLsL* gene, A member of the GRAS family transcription factor that inhibit production of lateral branching; DifF, Petunia DifF; DXMT, Dimethylxanthinemethyltransferase; ERF, Ethylene-responsive element binding factor; F3′5′H, Flavonoid 3′5′-hydroxylase; F3H, Flavanone 3-hydroxylase; F3′H, Flavonoid 3′-hydroxylase; *FaNES1*, *Fragaria ananassa* nerolidol synthase 1; *FT*, Flowering locus T gene; *GFP*, Green fluorescent protein; GLDH, L-galactono-1, 4-lactone dehydrogenase; GPDS, Gerbera phytoene desaturase; *GSQUA2*, Gerbera *SQUAMOSA-LIKE2*; *GUS*, Beta-glucuronidase gene; *HpaGxoo* gene, A member of the hairpin group of proteins that induces disease resistance and enhances growth in plants. Isolated from a Japanese strain of *Xanthomonas oryzae* pv. *oryzae*; Hpt, Hygromycin phosphotransferase; HyDFR, Hyacinth DFR; IP, Intellectual property; *LLA*, *Lycoris Longituba* agglutinin gene; Luc, Luciferase; MXMT, methylxanthinemethyltransferase; *N*-gene, Nucleoprotein gene; *Npt*II, Neomycin phosphotransferase II; NTSWV, Nucleocapsid gene of tomato spotted wilt virus; *Ace-AMP1*, An antimicrobial protein gene; *NtADH*-5′UTR, Alcohol dehydrogenase gene; *PAP1*, Production of anthocyanin pigment 1 (transcription factor MYB75); PAT, Phosphinothricin-*N*-acetyltransferase.; PCR, Polymerase chain reaction; *PGIP*, Polygalacturonase-inhibiting protein gene; Ph F3′5′H, Phalaenopsis F3′5′H; RLN, Root lesion nematode *Pratylenchus penetrans*; SUP, Superman is a zinc-finger transcription factor; *TOMSSF 5′*, The 5′upstream promoter regions of the tomato SuSy gene; XMT, Xanthosinemethyltransfease; ZM401, A pollen-specific gene of maize.

* Corresponding author.
E-mail address: azadip22@gmail.com (P. Azadi).

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1. Introduction

Ornamental horticulture has made an important impact within the horticultural industry. Usually, ornamental plants are used in gardening, landscaping, or as cut flowers. The total turnover for all aspects of floriculture is estimated to be more than 300 billion USD and cut flowers make up about one-third of the global value of the ornamental plants market (Chandler and Sanchez, 2012). Turnover of nine cut flowers in the FloraHolland auction are summarized in Table 1 (FloraHolland Key figures, 2015). Introduction of new cultivars with new characteristics such as novel flower color and plant architecture is one of the main goals of the ornamental plants industry. Although traditional hybridization and mutation techniques have been employed extensively to develop new varieties during the last decades, these techniques have a number of limitations and drawbacks, such as a high degree of heterozygosity and subtractive one-point improvement (Shibata, 2008). In recent, years genetic manipulation has been employed as a new route to overcome intrinsic barriers of traditional techniques.

Table 1
Turnover of nine cut flowers in the FloraHolland auction in 2015.

	Top 9 cut flowers sold	English name	Turnover (million Euros)
1	Rosa	Rose	735
2	Chrysanthemum	Chrysanthemum (Spray and disbudded)	363
3	*Lilium*	Lily	159
4	Gerbera	African Daisy	138
5	*Eustoma russellianum*	Lisianthus	52
6	*Alstroemeria*	Peruvian Lily	29*
7	Dianthus	Carnation	25*
8	Anthurium	Anthurium	25*
9	*Gladiolus*	Gladiolus	9*

* Data for 2014.

Cultivation of genetically modified (GM) crops increased in 2014, reaching 181.5 million hectares. The number of private companies and government research institutes which use genetic engineering to produce new crop varieties are increasing. Although the main aim of study is for food and feed use, with an emphasis on herbicide-tolerant and insect-resistant traits, more recently, there has been increasing interest on quality traits for industrial purposes (Parisi et al., 2016). Genetic engineering techniques facilitate cut flower breeding. A desired gene can be introduced into ornamental plants even if the gene does not exist in the natural gene pool (Chandler and Brugliera, 2011). Genes that improve pest and disease resistance in crops can also be used in ornamental plants. Traits such as color, fragrance, biotic and abiotic resistance, form and architecture of flowers, flowering time, and post-harvest longevity can be modified through genetic manipulation. Despite their value, few varieties of genetically engineered ornamental plants have been field tested, and the only genetic engineering ornamental products that have thus far been released for marketing are color-modified varieties of carnation and rose (Tanaka and Brugliera, 2013). In the present review, we have focused on the more recent literature on genetic modification of top nine important cut flowers; rose, *Lilium*, gerbera, chrysanthemum, lisianthus, *Alstroemeria*, anthurium, carnation, and *Gladiolus*.