BIOTECHNOLOGY IN ORNAMENTAL PLANTS: FUTURE PROSPECTS AND APPROACHES

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Abstract
Ornamental horticulture is a very important economic aspect of horticulture and plays a fundamental part in the way humans interact with and modify the environment. Floriculture is in turn a dominant sector of ornamental horticulture. Now, thousands of varieties of cut-flowers, pot plants, hanging plants, bedding plants, shrubs, lawn and turf, ornamental tree and aquatic plants are available to the public. Genetic engineering techniques has been used to develop many varieties of crop plants, but only a few varieties of ornamental plants. In this presentation, progresses in the development of transgenic ornamentals such as flower color modification, fragrance modification, abiotic stress resistance, disease and pest resistance, vase life and etc are reviewed and traits useful to both consumers and producers are identified.

Introduction

Ornamental horticulture is a very important economic aspect of horticulture, and floriculture is in turn a dominant sector of ornamental horticulture. Ornamental plants play a fundamental part in the way humans interact with and modify the environment. Plants having no medicinal or food value have been gathered and domesticated for thousands of years, purely because of the ornamental value of their morphology or flowers. Now, thousands of varieties of cut-flowers, pot plants, hanging plants, bedding plants, shrubs, lawn and turf, ornamental tree and aquatic plants are available to the public. In the developed economies, ancillary industries have evolved around floristry, gardening, landscaping and environmental amenity industries, all based around the use of ornamental plants (Dobres, 2011; Hall and Hodges, 2011). Along with the blooming markets, the international competition between countries and companies will be more and more intense. New cultivars with improved ornamental and agronomic traits are required urgently to increase the competition capacity.

Biotechnology vs. Traditional Techniques

In some ornamentals, development of new varieties through traditional technique methods is very difficult, laborious and lengthy, or is not an option if varieties are completely sterile, as in orchids (Da Silva et al., 2011). In these cases, GM provides an avenue for variety improvement. Recent advances in biotechnology enabled the use of various techniques such as tissue culture and mutation induction by UV, ionizing radiation, and also by chemical mutagens and "molecular breeding" by genetic transformation of specific genes of interest to raise the breeding efficiency.

Genetic Modification (GM)

Flower color: Flower color is one of the most prominent traits in breeding strategies, and flower markets and consumers demand a wide range of color variations in each crop. Three major flower pigments, flavonoids, carotenoids and betalains were responsible for the natural attractive display of plant colors (Grotewold E, 2006). Some specific colors were unavailable with conventional breeding methods in some species and genetic resources are not available for all floricultural plants. For example, roses, chrysanthemums, and lilies lack vivid blue flowers, and cyclamen and gentian lack yellow flowers. To overcome this problem, transgenic approaches are most promising; the first genetic engineering of flower color reported was the modification of flavonoid biosynthesis in petunia (Meyer et al., 1987).

Flower color modification via suppression technologies: Suppression technologies including RNAi, co suppression and antisense mediated silencing were more successful in flower color alteration (Nakatsuka et al., 2008; Tanaka et al., 2010; Winefield et al., 2009). White-flowered gentian was produced by suppressing the chalcone synthase (*CHS*) gene using an antisense method (Nishihara et al., 2006). White and pale-blue flowered gentian plants were produced with suppressed *CHS* or anthocyanidin synthase (*ANS*) genes by RNAi (Nakatsuka et al., 2008).

Flower color modification via introduction of foreign genes: Most flowering species exhibit limited flower colors which are attributed to limited kinds of pigments. Flavonoid 3', 5'-hydroxylase (*F3'5'H*) is a necessary gene in the biosynthesis of anthocyanins. Blue GM carnation were generated by overexpressing the *Viola F3'5'H* gene and great commercial success was achieved (Holton, 1996).

Flower color modification by regulating multiple genes: In some cases, deficient mutants accumulating suitable pigment precursors are necessary to achieve novel flower colors and transgenic floricultural plants with novel flower colors must be produced by manipulating multiple genes. The successful example of this method is blue rose, which have been sought for many years by all floricultural breeders, were also generated by transforming *viola F3'5'H* gene and overexpressing the *Iris hollandica DFR* gene (Katsumoto *et al*., 2007).

Flower color modification by other factors: Many other factors, along with pigments, are responsible for the formation of flower colors. It has been identified that vacuole pH (Verweij et al., 2008), pigments interactions and metal ion chelation affected color appearance (Colangelo and Guerinot, 2006; Shoji et al., 2010). There was no successful manipulation of GM plant via the regulation of above factors, though their genes have been isolated.

Fragrance: Fragrance could delight the customers which attracted many researchers on its components and unfortunately as a result of breeding, fragrance has been lost in many modern floral varieties. On the research of scent evolution, it was proposed that the emergence of the *OOMT1* gene may have been a critical step in the evolution of scent production in Chinese roses, which delineated a new picture about scent metabolism (Scalliet et al., 2008). *LIS* gene that coding S-linalool synthase is found in the scents of many flowers and has been isolated from *Clarkia breweri*. This gene and other genes derived from the same species are being used to modify scent in carnation and lisianthus (Lewinsohn et al., 2003).

Plant architecture: Cut flowers always need long and straight main stems, while pot plants always need to be dwarf and multi-flowering, therefore different architectures of ornamental plants are required according to sale styles. There are several genes that play essential roles in modification of plant architecture such as Lateral suppressor (*Ls*) gene and *DgLsL* isolated from chrysanthemum that causes less branching in plants (Han et al., 2007; Jiang et al., 2009). The products of *rolC* gene from the *Agrobacterium rhizogenes* are known to affect the endogenous cytokinin. Plants transformed with this gene, such as *Pelargonium domesticum* and *Petunia axillaris* performed dwarf phenotypes (Boase et al., 2004). Chrysanthemum transformed with isopentenyl transferase (*ipt*) gene involving in cytokinin biosynthesis, leading to increased branching and reduced internodes length (Khodakovskaya et al., 2009).

Flowering time: In floriculture industry, controlling flowering time is vitally important to ensure the flowers to be floriferous during important holidays, which will make the growers more profit. Transformation of chrysanthemum with *AP1*-homologous gene from chrysanthemum or *FT* gene from Arabidopsis has been shown to speed time to flowering (Jiang et al., 2010; Shulga et al., 2010).

Biotic stress resistance: Fungal, bacterial, viral pathogens and pests can have a devastating effect on ornamentals during production, storage, distribution and end-consumer use. Chemical control is still the predominant method to control these invaders, but is a significant cost for producers and environmental unfriendly. *Bt* genes have been widely studied in pest resistance breeding. Chrysanthemum transformed *Bt-Cry1A* showed strong pest resistance (Soh *et al*., 2009). The demonstration of aphid resistance in Chrysanthemum modified to produce caffeine is a recent significant development (Kim et al., 2011). With regard to virus resistance, the gene encoding the Chrysanthemum virus B (*CVB*) coat protein was transferred into chrysanthemum, the resistance to *CVB* was enhanced (Skachkova et al., 2006). Chrysanthemum transformed with N-methyl tranferases which involved in the caffeine biosynthesis pathway, exhibited strong repellence against insects, high resistance to virus and bacterial infection (Kimet al., 2010).

Abiotic stress resistance: For growers and consumers of ornamental plants, heat, light intensity, humidity and frost have an impact on the ability to produce a marketable product on schedule. Frost tolerance in *Petunia hybrida* may be increased by transfer of the *CBF3* gene from Arabidopsis (Warner, 2011) and this would potentially increase the range of environments in which this bedding plant could be grown. A heat shock transcription factors *LlHsfA2* isolated from *Lilium longiflorum* was proved to be correlated with heat tolerance of lily (Xin et al., 2010).

Vase life and keeping quality: As cut flowers must have the capacity to survive several weeks in the distribution chain before they reach consumers' hands, resistance of flowers to senescence promoting factors such as ethylene and bacterial infection is very important. Enhanced vase life could be obtained by the introduction of resistance to ethylene or by the inhibition of expression of endogenous ethylene biosynthesis genes. Carnation transformed with the genes encoding *ACO* from carnation or *ACS* from apple, exhibited longer vase life than control (Inokuma *et al*., 2008).

Future prospects and approaches

There are some specific characteristics in ornamental plants, such as fragrance, diversity of flower colors and shapes, consequently promote the research on these areas. Biotechnologies renew every day; the researchers in ornamental horticulture should take advantages of these technologies and their own specifications, and finally promote the development of research and industry. Here are some biotechnology approaches which are suggested to be widely used in ornamental plants:

- The application of bioinformatics (the sequencing and analysis of genome, transcriptome and proteome in plants) in ornamental plants.
- Using of the new methods for identification of gene function such as reverse genetic approach and RNA interference (RNAi) that is a post-transcriptional gene silencing mechanism which has been used as a technique for reverse mutagenesis in plants in order to identify genes involved in a particular localized process.

References

CHEN, X.-L., LIU, F.-Luan., YANG, H.-f., ISHAK, A., LI, J.-X., MA, N. and ZHAO, L.-J. (2012) Biotechnology in Ornamental Horticulture. 20(6): 682~694

Da Silva, J.A.T., Chin, D.P., Van, P.T. and Mii, M. (2011) Transgenic orchids. Sci. Hort. 130, 673–680.
(Warner, 2011)

Dobres, M.S. (2011) Prospects for commercialisation of transgenic ornamentals. In Transgenic Horticultural Crops; Challenges and Opportunities (Mou, B. and Scorza, R., eds), pp. 305–316. Boca Raton, FL: CRC press.

Kim, Y.-S., Lim, S., Kang, K.-K., Y-J., Lee., Y-H., Choi. and Y-E. And Sano, H. (2011) Resistance against beet armyworms and cotton aphids in caffeine producing transgenic Chrysanthemum. Plant Biotechnol. 28, 393–395.

Tanaka, Y., Brugliera, F., Kalc, G., Senior, M., Dyson, B., Nakamura, N., Katsumoto, Y. and Chandler, S. (2010) Flower color modification by engineering of the flavonoid biosynthetic pathway: practical perspectives. Biosci. Biotechnol. Biochem. 74, 1760–1769.