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REVIEW ARTICLE

Enhancing floral diversity: A review of mutation breeding techniques in flower crops

Vishwanath S[1], Rajangam J[2*], Rajadurai K.R[1], Gnanasekaran M[3], Anitha T[4] , Ravi R[1] & Venkatesan K[5]

[1]Department of Floriculture and Landscaping, HC & RI, TNAU, Periyakulam, Tamil Nadu - 625 604, India

[2]HC & RI, TNAU, Periyakulam, Tamil Nadu - 625 604, India

[3]Department of Fruit Science, HC & RI, Periyakulam, Tamil Nadu - 625 604, India

[4]Department of Post Harvest Technology, TNAU, Periyakulam, Tamil Nadu - 625 604, India

[5]Department of Floriculture and Landscaping, HC & RI,TNAU, Periyakulam, Tamil Nadu - 625604, India

*Email: jrajangam2016@gmail.com

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Abstract

Flower crops encompass a wide range of ornamental annuals and perennials that are commercially cultivated for aesthetic appeal of their floral displays. Mutation induction has been used since the early 20th century to increase genetic diversity and develop new flower varieties with improved yield, quality, adaptation and market value. Mutation experiments have successfully created genetic variability and novel phenotypes in diverse floral species. Mutation breeding, which involves the induction of genetic variations via physical and chemical mutagens, has emerged as a vital technique for enhancing ornamental plant traits, such as flower color, shape, disease resistance and stress tolerance. It explores the types and applications of physical mutagens, such as gamma rays and ion beams and chemical mutagens, such as ethyl methane sulfonate (EMS) and sodium azide (SA). This review provides detailed insights into mutation breeding research conducted on major flower crops (e.g., rose, carnation, chrysanthemum and gerbera). This study also highlights achievements in the development of novel flower varieties, highlights the key challenges faced in mutation breeding programs and identifies gaps in research, particularly concerning the comparative efficacy of different mutagens, environmental impacts and genetic stability of mutated varieties. Furthermore, the impact of mutation breeding on the global flower market is discussed, emphasizing its role in expanding trait diversity, catering to niche markets and enhancing the commercial value of flower crops. Mutation breeding offers significant promise in the development of sustainable and climate-resilient ornamental crops that can meet the needs of emerging markets. This review serves as a valuable resource for students, scientists and breeders interested in leveraging mutation breeding for floral crop improvement.

Keywords

Flower crops; floriculture; induced mutations; physical mutagen; chemical mutagens; crop improvement

Introduction

The International Floriculture Industry, which includes cut flowers, potted plants, bedding plants and loose flowers, has expanded dramatically over the past few decades into multibillion-dollar enterprises. As income levels rise globally, the demand for floricultural commodities is increasingly driven

by sociocultural traditions, religious connotations, aesthetic considerations, gifts/bouquets, landscaping uses and health benefits (1). One major challenge is the limited understanding of transformation and regeneration procedures for numerous ornamental species, with many of those studies proving to be exceptionally difficult (2). Mutations constitute the fundamental source of all genetic variation that serves as the foundation for evolution and is a useful strategy for enhancing the economic traits of plants. These genetic changes can occur naturally at a very low frequency or can be induced experimentally via physical and chemical mutagens (3). Mutation breeding has resulted in thousands of improved varieties with relatively high yields and improved tolerance to pests, diseases and environmental stresses. It has become a cornerstone of modern plant breeding, alongside recombinant and transgenic breeding methods.

The discovery of X-rays by Roentgen in 1895, radioactivity by Becquerel in 1896 and radioactive elements by Marie and Pierre Curie in 1898 paved the way for the intentional induction of mutations in plants (4). Naturally occurring modifications in the deoxyribonucleic acid (DNA) of organisms represent a vital source of genetic variability that, through the mechanisms of natural selection and genetic drift, has resulted in the evolutionary progression and expansion of numerous plant species recognized today. These alterations, referred to as mutations, have also engendered variations among numerous plant species. Mutations constitute a pivotal source of enhancements within a variety of ornamental species (5). Genetic engineering is mostly deemed impractical for the breeding of ornamental plants since the high costs coupled with obtaining patents and licences for techniques and gene modification are relatively high. In addition to expensive approval and registration processes for genetically modified ornamental plants, that hinders the use of genetic engineering and reduces the profitability of genetically modified plant producing breeding companies (6). Hybridizing existing cultivars with other germplasms is frequently challenging, necessitating alternative methods for introducing genetic variation (7).

Hence, mutation breeding is the best alternative for ornamental plant improvement. In this review, the role of physical mutagens in facilitating precise and targeted modifications of plant DNA and their application in ornamental plant breeding are highlighted. Along with, the use of ethyl methane sulfonate (EMS) and other alkylating agents, X-rays, gamma rays, fast neutron irradiation and heavy ion irradiation and their effects on flower crops have been reviewed and discussed (8). This is followed by a detailed compilation, highlighting mutation breeding research undertaken in major flower crops, *viz.,* rose, carnation, chrysanthemum, gerbera, eustoma and antirrhinum, their key explants targeted, the mutagens and doses used, the improved traits and commercial mutant cultivars released from a crop wise perspective to assess the progress of mutagenesis studies spanning the past five decades have also been dealt out. Subsequently, this paper also elucidates the constraints that were encountered in mutation programs along with emerging opportunities through new breeding technologies. Hence, this review comprehensively documents global research efforts, commercial achievements and technological innovations pertaining to the application of mutation breeding for genetic enhancement in flower crops.

Types of Mutagens

Mutations that are induced in an organism via physical or chemical mutagens are called induced mutations. The agents that are used to induce mutation are called mutagens. Mutations are generated through the application of physical agents (such as gamma radiation and beams of both high and low energy) and chemical agents (including ethyl methane sulfonate, abbreviated as EMS) in the treatment of both seed and vegetatively propagated crops. Extensive research on mutagenesis in flowering plants via physical and chemical mutagens has focused on both applied and fundamental aspects, such as radiosensitivity; the choice of plant material; methods for gamma (γ) ray exposure; optimal γ-ray dosages; colchicine treatments; repeated irradiation and the identification, isolation and commercial use of mutants (9). The induction of genetic variability may be facilitated by mutagenic agents, including radiation and chemical substances, from which advantageous mutants can subsequently be isolated. Furthermore, alterations may also transpire within cytoplasmic organelles, potentially leading to chromosomal or genomic mutations that enable plant breeders to select beneficial mutants, such as those exhibiting specific flower colours, flower morphologies, disease resistance or early flowering traits (10). A notable benefit of inducing mutations lies in the capacity to acquire unselected genetic variation, thereby enhancing vegetatively propagated plants when modifications are desired for one or a limited number of traits in an exceptional cultivar. primarily, investigations are being undertaken concerning methodologies related to physical and chemical mutagenesis techniques.

Physical mutagens

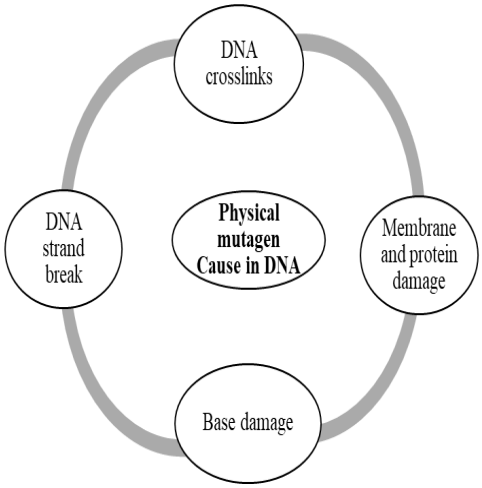
Over the preceding 8 decades, physical mutagens, predominantly ionizing radiation, have been extensively employed for the induction of hereditary aberrations, with over 70 % of mutant varieties generated through physical mutagenesis (11). Ionizing radiation, which comprises gamma rays, X-rays, protons, neutrons and alpha particles, has been most extensively employed as a physical mutagen because of its high penetrability and mutagenic efficiency. However, gamma rays emitted from radio isotope sources such as cobalt-60 and caesium-137 induce high mutation rates across most flower species (12). A short time span can be achieved by producing new, promising mutant varieties of ornamentals through the application of appropriate tactics for mutation induction, such as the combination of chronic gamma irradiation and *in vitro* culture techniques. Since it causes higher mutation frequencies than X-rays and gamma rays do, ion beam radiation has become a unique and effective mutagen for ornamental plant development over the past 20 years (13). Gamma rays are frequently and successfully employed to induce mutations in floriculture, with heavy-ion beam

(HIB) being recently used for inducing mutations in crucial ornamental plants such as chrysanthemum, orchids, roses, pelargonium, cannas and carnations, which are available in both cut and potted forms. X-rays, another category of ionizing radiation are capable of deleting base pairs and breaking chromosome strands (Fig. 1). Ultraviolet radiation causes the formation of pyrimidine dimers between adjacent nucleic bases, thereby interrupting DNA replication and gene expression patterns. Although less penetrative than gamma rays are UV rays represent an efficient physical mutagen for flowers that propagate through cuttings. Overall, while physical mutagens offer simplicity of use and high frequencies of heritable mutations, they require expensive radiation equipment and trained personnel for safe handling (14). Conditions and effects of gamma and X-ray treatment (Table 1).

Chemical mutagens

In comparison with physical mutagens, certain alkylating agents and analogous chemicals easily penetrate plant cells and effectively modify nucleic acid bases. Ethyl methane sulfonate (EMS), N-nitroso-N-methylurea (NMU), N-nitroso-N-ethylurea (NEU), methyl methane sulfonate (MMS), diethyl sulfate (DES), ethylene imine (EI) and N-nitrosoguanidine (NTG) are commonly employed chemical mutagens in flowers**.** Alkylating and DNA intercalating substances are also chemical mutagens. Lethality, sterility and a decreased capacity to regenerate plants from tissues such as floral pedicels are among the harmful outcomes that might result from EMS (15). Sodium azide was used to induce phenotypic variation in *Chrysanthemum morifolium* plants (16). Thus, chemical mutagens not only complement physical mutagens but also, in some cases, help to overcome interspecific sterility barriers. However, these chemical substances present challenges of residual toxicity and necessitate elaborate safety measures during mutagenic treatments. The concentrations of EMS varied from 0.02 % to 5 %, with one concentration being particularly high at 40 %. The treatment durations ranged from 10 to 48 h (Table 2).

Fig. 1. Physical mutagen causes in DNA.



Mutation breeding research in major flower crops

Induced mutagenesis has been widely explored across diverse floricultural species, leading to some key successes in the development and release of commercial mutant varieties. This section documents details of mutagenesis experiments undertaken in several major cut flower crops. The types of mutagenic treatments imposed on different explants, key traits targeted for improvement and novel genetic stocks or cultivars bred are described in this section.

The physical and chemical mutagen-induced variations in flower cultivars/varieties are listed in Table 3 and 4.

Rose

Owing to its popularity worldwide as a cut flower and garden plant, rose has remained a highly amenable species for induced mutagenesis studies for decades. Radiation treatments include gamma rays from Cobalt-60/ Caesium-137 sources, X-rays and fast neutrons. EMS and sodium azide are commonly applied as seed soaking treatments. Mutagenic treatments include targeted shoot tips, dormant cuttings, *in vitro* shoot cultures and embryogenic calli in addition to seed materials. Key traits improved through the selection of induced mutants include variation in flower color, size, fragrance and recurrent flowering ability as well as enhanced resistance to biotic stresses such as powdery mildew, black spot and rose mosaic virus. The Indian rose mutant variety is shown in Fig. 2.

Table 1. Conditions and effects of gamma and X-ray treatment**.**

Flower name	Material	Mutagen	Dose (krad)	Effect	Reference
Antirrhinum	Seeds	Gamma rays	10-320	Lethal $Dose_{50}$ value for Survival of plant species	(38)
			0.5-60		(39)
Chrysanthemum	Cuttings		1-4		(40)
	Ray florets		0.5-1		(41)
	Cuttings	X-rays	0.44-1.75		(40)
	Cuttings	Gamma rays	0.5-2.5		(42)
	Cuttings		1-2		(43)
	Cuttings	X-rays	0.5-2		(44)
Gladiolus	Corms		1.5-5.5		(45)
Jasminum spp	5	Gamma rays	1-2.5		(46)
Rosa spp	Shoot tips		1-6		(47)
	Stem cuttings with bud		0.5-8		(48)
	Microshoots	X-rays	2.5-6		(49)

Table 2. Conditions and effects of ethyl methane sulfonate (EMS) treatment.

Flower name	Material	Mutagen	Treatment concn	Treatment duration	Effect	Reference
Rosa spp	Apical and axillary meristems	EMS	0.50 % to 3.00 %	2-12 h	Lethal Dose$_{50}$ value for Survival of plant species	(50)
	Stem cuttings with buds		0.08 % to 5.00 %	1-24 h		(51)
Antirrhinum	Seeds		0.10 % to 1.00 %	8-12 h		(52)
Chrysanthemum	Leaf sections		0.025 % to 0.050 %	5 h		(41)
Bougainvillea	Cuttings		0.80 % to 1.00 %	6 h		(53)
Gladiolus	Corm buds		0.20 % to 1.20 %	Unknown		(54)
	Corms		0.25 % to 1.25 %			(55)
Gerbera	Shoots		0.10 % to 1.00 %	10 min		(56)
Dianthus	Seeds		0.10 % to 0.70 %	6 h		(15)
Jasminum spp	Cuttings		0.06 % to 0.62 %	1-6 h		(46)
			0.25 % to 0.4 %	1 h		

Table 3. Physical mutagen-induced variations in flower cultivar/variety.

Sl. No.	Crop	Mutagen	Cultivar/variety	Variation	Reference
1	rose	Gamma rays with (4 Kr)	Garden rose Bettina (bud)	white to very high pink (Petal colour)	(32)
			Garden rose Lady Florence Strong (bud)	Dark to lighter (Petal colour)	
			Garden rose President Poincare (bud)	Dark to lighter (Petal colour)	
		40 Gy	*In vitro* mutagenesis *(Rosa hybrida* L.*)*	Red to white (Petal colour)	(48)
		70 Gy	Aqua' cultivar	red-purple to white pink petals	(57)
			Yellow babe	Yellow to orange petals	
			Vital cultivar	orange red	
2	Carnation	450 Gy gamma rays	pink carnation	Vase life increase 0 to 2 days (room temperature)	(58)
			white carnations	Vase life increase 5 days (room temperature)	
3	Chrysanthemum	10 Gy gamma ray	(*Chrysanthemum morifolium)* purple colour	Deep purple to light purple	(59)
		10 Gy gamma ray	*Chrysanthemum morifolium*	Purple to dark purple	(60)
		20 Gy gamma ray	*Chrysanthemum morifolium*	Purple to dark red	
4	Gerbera	5 Gy gamma ray	*Gerbera jamesonii* Hook.	Increase in Total protein content (72.89) (mg g^{-1} FW)	(56)
		1.5 Gy gamma ray	*Gerbera jamesonii* Hook. Harley' cultivar	Increase flower diameter (6.19 cm)	(61)
		5 Gy gamma ray	*Gerbera jamesonii* cv. 'Harley'	moderately resistant to powdery mildew	(62)
5	Tuberose	5 Gy gamma ray	Tuberose Var 'Hyderabad Single'	Increase number of tillers	(63)
		2000 Gy gamma ray	Tuberose Sikkim Selection	Increase Diameter of floret (3.03 cm)	(64)

Table 4. Chemical mutagen-induced variations in flower cultivar/variety.

Sl. No.	Crop	Mutagen	Cultivar/variety	Variation	Reference
1	Rose	0.2 and 0.3 % EMS for 4 h	*Rosa persica* Michx	Seedling and leaf lengths were longer	(65)
		0.3 % EMS for 8 h		Decline the seeds per hip and increase the necrotic buds	
2	Carnation	EMS (0.75) %	Carnation cultivar Pink Donna	Increase diameter of flower (cm)	(66)
		MMS (0.1) %		Increase plant height (cm)	
		0.075 and 0.100 % EMS (MS)	*In vitro* mutagenesis carnation cv. Espana	Red to red colour mutant with white stripes along with petal length	(67)
		0.75 and 1.00 % EMS (EA)	*In vitro* mutagenesis carnation cv. Espana	Red to pink with white stripes	
3	Chrysanthemum	(0.5 %) EMS	*Dendranthema grandiflora* L.	first flower opening 48.45 days	(68)
		(0.1 % EMS)	*Dendranthema grandiflora* Tzvelve. Root cutting	Leaf variation	(69)
4	Gerbera	1.0 % EMS	*Gerbera jamesonii* Hook.	Increase in total protein content (74.26 mg g^{-1} FW) and phenolics content (14.09 mg g^{-1} FW)	(56)
		0.2 %/10 min EMS	*Gerbera jamesonii* Hook. 'Harley' cultivar	Increase flower diameter (6.56 cm)	(61)

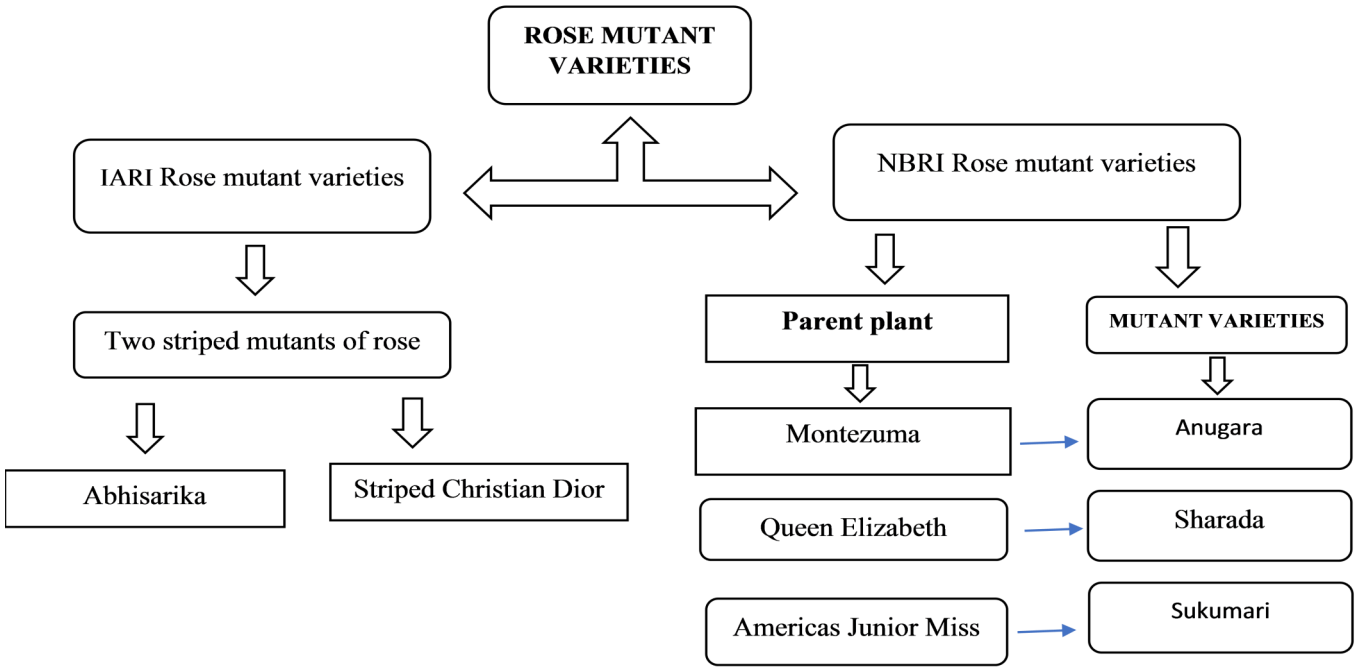


Fig. 2. Rose mutant varieties (36, 37).

1. 'Twinkle' (pink stripe on a cherry red background) was developed from an 'imperator' with cherry red flowers irradiated with gamma rays.
2. 'Contempo Stripe' (yellow stripe on orange background) developed from rose cv. 'Contempo' (orange petal with yellow eye) irradiated with gamma rays.
3. 'Mrinalini Stripe' (white stripe on pink background) developed from 'Mrinalini' (pink) irradiated with gamma rays (17).

All the above mentioned striped mutants have been commercialized and are in high demand on the market both as cut flowers and as potted plants. Induced mutants also serve as key genetic resources for developing new hybrids and studying the functional genomics of horticultural traits in rose.

Carnation

As an important commercial cut flower, carnation (*Dianthus caryophyllus*) has undergone extensive mutation breeding programs since 1940 to explore the use of various physical and chemical mutagens. Treatments imposed on shoot apices, nodal segments and callus cultures have created a wide spectrum of flower color and shape variations. Key agronomic traits, such as enhanced resistance to *Fusarium* wilt, improved productivity and longer vase life, have also been successfully achieved through induced mutagenesis. More than 13 new varieties with altered flower color have been commercialized through X-ray and EMS treatment (18, 19). Carnations are among the earliest plants to be included in mutation breeding programs, with the first reported mutants exhibiting changes in flower color and types (19). The first transgenic carnation plant was created in 1989 via

in vitro mutation via *Agrobacterium* (20). Transgenic carnations with ethylene-forming enzyme (EFE) and 1-aminocyclopropane-L-carboxylic acid (ACC) synthase genes have been created, resulting in a reduction in senescence and an increase in vase life (21). X-irradiation of *in vitro* petal growth to create a variety of mutations in carnation (22). Carnation node cultures treated with X-rays presented flower color variations (23). The Indian Institute of Horticultural Research, Bengaluru, released the first variety in India, the Arka Flame, as a result of *in vitro* mutation breeding. Recently, another variety, Arka Tejas, was released (Fig. 3, 4). Mutation breeding experiments were conducted at IARI, New Delhi. After carnation seeds were irradiated with gamma rays for 6 to 20 h, some intriguing mutants with variegated leaves were discovered (24).

Fig. 3. Arka Flame mutant variety of carnation.

Fig. 4. Arka Tejas mutant variety of carnation.

Chrysanthemum

Owing to its natural diversity and heterozygous genome, chrysanthemum offers high amenability for the induction of genetic variation through physical or chemical mutagens. Accordingly, mutagenic treatments have been studied rather extensively in chrysanthemum to alter flower shape, size, color, photoperiod sensitivity and response to biotic and abiotic stresses. There have been reports of 198 commercial mutant variants from different nations (25). A majority of the mutants were developed via x- or gamma-ray irradiation. The characteristics of the mutants included flower color, shape and size in addition to their physiological characteristics. Colchicine (0.0625 %) has been successfully used for the development of flower color mutations in the chrysanthemum cultivar Sharad Bahar. The original color of Sharad Bahar was purple, whereas the mutant color was Terracotta Red. The mutant has been named 'Colchi Bahar'(26-28). The recurrent irradiation approach has been used for chrysanthemum mutation breeding. In populations subjected to repeated radiation, a wider range of genetic diversity (mutation frequency and spectrum) was observed (29). The National Botanical Research Institute released more chrysanthemum mutant varieties (Fig. 5, 6).

Gerbera

Owing to the slowness of the standard vegetative propagation approach, tissue culture micropropagation has been created for large-scale manufacturing to fulfil commercial demand. The irradiation of Gerbera *in vitro* shoots has resulted in the induction of several mutants/ variants with altered flower color and morphology (30). Radiation treatment of an *in vitro* gerbera cultivar that is pink resulted in the induction of approximately 19 variations, including changes in bloom shape and color. Mutation induction via various physical and chemical agents is a common breeding strategy for improving plants. The strength of the mutagen dose had a significant effect on the percentage survival of shoots. The highest survival percentage was observed in cultures treated with the lowest dose of gamma rays (1.5 Gy).

Tuberose

Tuberose (*Polianthes tuberosa* L.) is a fragrant cut flower popular in the tropical and subtropical regions of India. There is an urgent need for well-planned breeding programs using conventional and nonconventional breeding techniques to increase the degree of variation in biotic and abiotic traits such as disease resistance, flower shape and

Fig. 5. National Botanical Research Institute (NBRI), released chrysanthemum mutant varieties.

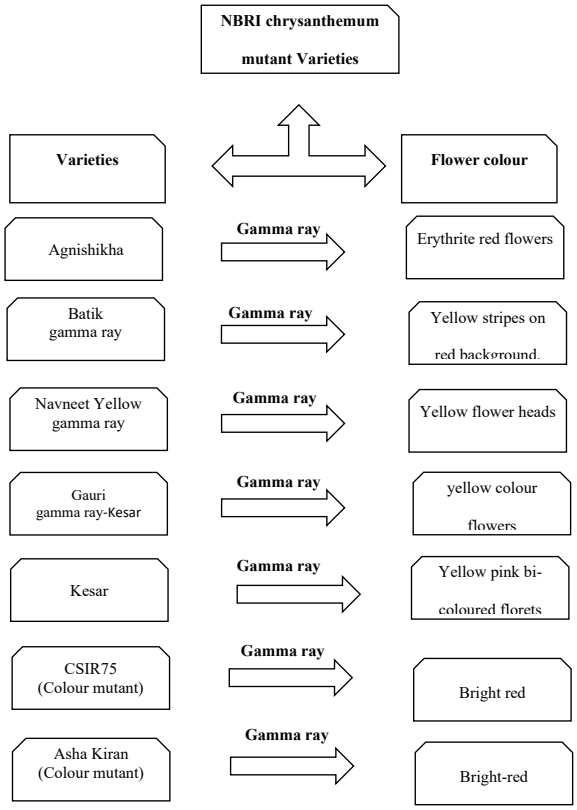


Fig. 6. Chrysanthemum mutant varieties in India.

vase life in tuberose. Owing to self-incompatibility, conventional breeding methods involving hybridization in tuberose have some limitations (31). Mutation breeding appears to be a well-standardized, efficient and cost-effective technique that can be used to create new species. Two chlorophyll variegated mutants, "Rajat Rekha" (leaves with silvery white streaks along the middle of the blade, induced in single-flowered tuberose) and "Swarana Rekha" (leaves with golden yellow streaks along the margin, induced in double-flowered tuberose) were developed by gamma rays (2 Krad) and commercialized (Fig. 7) (32).

Eustoma

Eustoma grandiflorum, a recently introduced flower crop on the global market, is a moderately cold-resistant plant that completes its life cycle annually or biennially. Tissue culture propagation of *Eustoma grandiflorum* is currently inefficient. Among biotechnological breeding approaches, mutation induction stands out as a potent method. The acclimatized plants presented the highest survival rate (95 %) and the greatest number of branches and branch length (cm) were recorded when the plants were subjected to 20 min of exposure to the green laser. Conversely, the majority of the highest floral parameters and anthocyanin pigment contents in flowers, along with anatomical structural parameters, increased with the use of a 20 min blue laser treatment, 20 and 25 min of green and red laser treatments respectively (33).

Bougainvillea

One of the most significant tropical and subtropical perennial ornamentals is *Bougainvillea* spp., with a wide range of variations and cultivars with significant floral

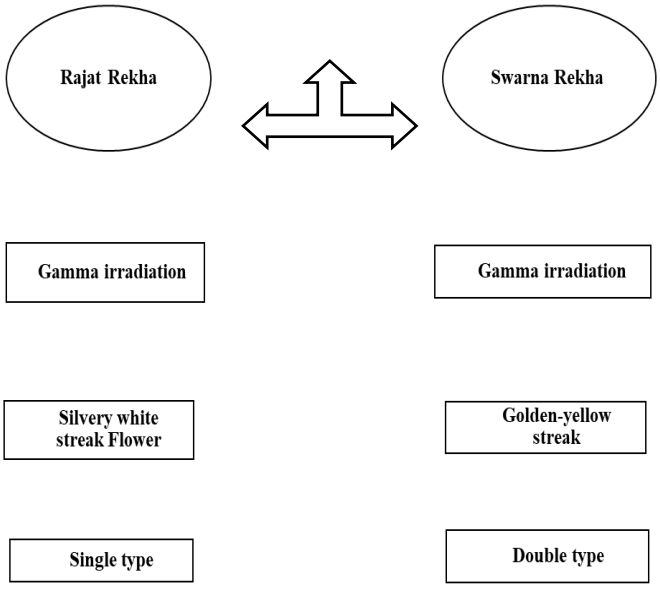


Fig. 7. Tuberose mutant varieties in India.

value. The radio sensitivities of the stems of many bougainvillea cultivars (single or double-bracted) to gamma rays have been determined from large-scale induced mutagenesis experiments (34) and the optimal level was determined to be 0.25-10 Krad (17). Some of the most promising and beautiful chlorophyll variant mutants induced by irradiation include ‘Arjuna’, ‘Pallavi’, ‘Mahara Variegata’ and ‘Los Banos Variegata’. The proportion of sprouts decreased when the gamma irradiation dose increased from 0 to 2000 rads. Among the cuttings, the highest rate of 1`s sprouting (94.00 %) was noted under the 500 rad gamma ray treatment, which was very different from the other treatments. However, cuttings treated with 2000 rad gamma radiation presented the lowest rooting percentage (41.0 %). The results showed that light color variation in foliage/bract could be determined, but it will be seen in the next generation for conformity (35). National Botanical Research Institute (NBRI) -“A.P.J. Abdul Kalam” in 2015 (Fig. 8) by the National Botanical Research Institute (NBRI), introduced a novel spontaneous variation featuring striking leaves with variegation, blending three distinct colours: green, yellow and yellow ash. Additionally, this mutant presents large, twisted bracts and flowers during the winter period. Induction of bougainvillea mutants via physical and chemical mutagens (Table 5).

Fig. 8. A.P.J. Abdul Kalam mutant variety.

Table 5. Induction of bougainvillea mutants via physical and chemical mutagens adapted (70).

Sl. No.	Original variety	Characters	Mutagen	Mutant name	Characters
1	(Double bracted) Los Banos Beauty	Mallow purple colour, green leaves, persistent bract	Gamma rays	(Variegata) Los Banos	Cream-white, light and dark green variegated leaves with a pinkish-purple bract that is not persistent
2	(Double bracted) Mahara	Rhodamine purple colour bract, Green leaves, bract persistent	Gamma rays	(Variegata) Mahara	Variegated leaves with a cream-colored yellow edge and a green center, a persistent bract that is the color of rhodamine
3	(Double bracted) Roseville's Delight	Burnt orange bract color, persistent bract and green foliage	Gamma rays	Pallavi	Variegated leaves with a noticeable variegation in the young shoots and foliage, a persistent bract with a burnt orange color
4	(Double bracted) Los Banos Beauty	Green foliage, a tenacious bract, with a mallow purple hue	0.02 % EMS	Los Basnos Variegata Jayanthi	Variegated leaves with a persistent bract, light green and green in the center, and creamish yellow and white on the border
5	(Single bracted) Pixie	Green, bract-shaped, pinkish-purple, nonpersistent leaves	0.02 % EMS	(Variegata) Pixie	Small leaves with variegation, a green center, a cream-colored, white and light yellow edge and a pinkish-purple, nonpersistent bract

Research Gap

Despite significant research on mutation breeding in flower crops, comprehensive analyses of the effectiveness of various mutagens are lacking. Additionally, there has been limited exploration of the potential environmental impacts and safety concerns linked to mutation breeding techniques in these crops. The genetic stability and long-term sustainability of mutated flower varieties also require further investigation. Moreover, comparative studies between traditional breeding methods and mutation breeding techniques in flower crops are rare, underscoring a critical gap in current research. Mutagen breeding had a considerable impact on the global flower market by contributing to the development of novel and diverse ornamental varieties that appeal to different consumer preferences and cultural aesthetics. By expanding the range of available traits, such as unique colors, shapes and sizes, mutagen breeding has allowed breeders to cater to niche markets and seasonal demands, increasing the commercial value of flower crops. This innovation has enabled regions with emerging flower industries to compete more effectively in the international market, fostering growth and diversification in the global floriculture sector.

Conclusion

In summary, mutation breeding has greatly improved conventional hybridization methods, helping maintain genetic diversity in new floricultural varieties over the past several decades. Induced mutagenesis has expanded the diversity of ornamental traits (such as color, shape and size), yield characteristics, adaptability and resistance to biotic stresses. This approach has been widely adopted by key research institutions and commercial breeders globally, resulting in the release of over 1000 officially recognized mutant varieties across 170 different ornamental species. The effectiveness of mutagenesis has further increased when mutagenesis is combined with advanced molecular biology techniques and *in vitro* culture methods, providing a significant boost to crop improvement and breeding programs, particularly in the face of global climate change. However, challenges related to mutagenic efficiency, mutation types, sterility and screening capabilities highlight the need to incorporate new-generation breeding technologies to further enhance product development. A well-integrated approach combining traditional mutagenesis methods with advanced genomic tools and targeted genome editing techniques could drive the next phase of floricultural innovation to meet the growing demands of both growers and consumers. Mutation breeding holds significant promise in the development of sustainable, climate-resilient ornamental crops that can thrive under changing environmental conditions. By focusing on traits that increase water-use efficiency, disease resistance and adaptability, mutation breeding can also help to meet the needs of emerging markets where floriculture is rapidly expanding. Such efforts could pave the way for more sustainable production practices and a wider range of ornamental options for global consumers. This review provides a comprehensive compilation and critical analysis serving a valuable knowledge and reference for students, scientists and breeders considering the use of mutation breeding, particularly for floral crops.

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