Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 04 (JULY-AUG, 2026)
Available online at http://www.agriarticles.com

CRISPR Gene Editing for Developing Climate-Resilient Ornamental Flowers

*Sourabh Sherawat[1], Ram Krishna Choudhary[2] and Kumar Aryan[3]
[1]M.Sc. (Ag.) Horticulture, Department of Floriculture and Landscape Architecture, KNK College of Horticulture, Mandsaur, RVSKVV, Gwalior, Madhya Pradesh, India
[2]Ph.D Scholar, Department of Floriculture and Landscaping, Pt. K.L.S. College of Horticulture and Research Station, Rajnandgaon, MGUVV, Sankara, Durg (C.G)
[3]M.Sc. (Ag.) Horticulture, Department of Horticulture, Hemvati Nandan Bahuguna Garhwal University, Uttarakhand
*Corresponding Author's email: sourabh7078@gmail.com

Climate change poses a significant threat to ornamental flowers, making them one of the most vulnerable horticultural products. Drought, heat waves, saline intrusion, and new pests and diseases all have a direct effect on how healthy plants are, how long they bloom, how bright their colors are, and how easy they are to sell. Some stress-tolerant ornamental plants have been created through traditional breeding, but progress has been slow because of long generation times, complicated and sometimes polyploid genomes, and stress-response mechanisms that aren't well understood. CRISPR/Cas genome editing offers a unique opportunity to develop climate-resilient ornamentals by making precise modifications to pathways that control responses to biotic and abiotic stress while maintaining or even improving aesthetic qualities. This study gives an overview of the current state of CRISPR use in ornamental flowers, with a focus on how these methods could be used to make them more resistant to problems caused by climate change. First, we talk about the problems with traditional breeding and how climate change affects the production of ornamental plants. After giving an overview of the main CRISPR/Cas platforms and delivery methods for horticultural crops, we show how genome editing has been used to change the color, shape, and age of flowers in ornamentals like petunia, torenia, chrysanthemum, carnation, lily, gentian, and others. We discuss gene targets and regulatory networks for improving drought, salinity, heat, and cold tolerance, along with disease resistance and floral longevity under stress, drawing from extensive research in field crops. We focus on technologies that make it possible for things like effective transformation and regeneration systems, multiplex and transgene-free editing methods, and multi-omics methods for identifying ornamental genes. To ensure the future of the ornamental flower industry, we will finally talk about biosafety, regulatory, and socioeconomic issues. We will also show how to combine CRISPR with smart phenotyping and climate-adaptive production. This paper contends that climate-resilient ornamentals represent a viable short-term objective by integrating the swiftly growing body of CRISPR research in crops with emerging developments in floriculture, provided that technological, legal, and perceptual obstacles are systematically dismantled.

Summary

Ornamental flowers make the world a better place for people, cities, and the environment. The combined value of cut flowers, potted plants, and landscape ornaments is worth billions of dollars because of rising demand in both developed and developing economies. Floriculture, on the other hand, is especially at risk from climate change. Short periods of extreme heat, drought, salt, or flooding can cause buds to drop, flowers to lose size and color, plants to die early, and plants to be more susceptible to pests and diseases. These effects lead to lower yields, worse quality, and higher production costs for farmers. Some of the problems with traditional breeding, mutation breeding, and transgenic approaches, which have been used to improve ornamental traits, are that crops like roses and chrysanthemums have complex polyploid genomes, strong selection for aesthetic traits that may not be good for stress tolerance, and limited genomic resources compared to major food crops. Clustered regularly interspaced short palindromic repeats (CRISPR) and associated nucleases (Cas) have emerged as efficient instruments for precise, rapid, and cost-effective genetic enhancement in this context. CRISPR/Cas was first widely used in model plants and staple crops. Now, it is being changed so that it can be used on fruit, vegetables, and ornamental plants. Recent evaluations indicate that genome editing has progressed from mere proof-of-concept to the development of ornamental traits, encompassing flower color, architecture, and longevity. The next logical step in redirecting some of this innovation toward climate resilience is to change the genes and regulatory networks that help ornamental flowers keep their beauty under stress and adapt to growing conditions that are becoming more unpredictable.

Climate change and the ornamental flower sector

Abiotic stress affects ornamental plants

Drought and heat are two of the most important weather-related problems in floriculture. Plants grown in pots, containers, greenhouses, and urban areas often have soil that dries out and warms up quickly. When there isn't enough water, many ornamental plants have smaller leaves, shorter shoots, smaller flowers, and less pigment buildup, which directly lowers their decorative value and market price. Drought also speeds up aging and makes cut flowers last less time in a vase. More and more, salinity is important because of the use of marginal water, saline irrigation sources, and soil degradation. When ornamental plants are stressed by salt, their leaves burn, they get chlorosis, they don't flower as much, and their branches change shape. Transcriptomic and physiological investigations demonstrate that ornamental species react via abscisic acid (ABA) signalling, ion homeostasis, and osmolyte accumulation pathways akin to those observed in food crops, although species-specific sensitivities may be significantly pronounced. Extreme cold and heat affect not only survival but also the shape and fertility of flowers. High temperatures can cause buds to die, pollen to become sterile, pigments to lose their stability, and faster postharvest deterioration. On the other hand, low temperatures can slow down flowering, cause chilling damage, and lower pigment production. Changes in the climate that make pests and diseases more common make it even harder to grow ornamental plants. This is because many insect pests and pathogens spread to new areas and have more generations each season when it gets warmer.

Problems with traditional breeding

Efforts to select or cross for abiotic stress tolerance in ornamentals have produced a few tolerant cultivars, but progress is slow and mostly based on trial and error. A lot of ornamental plants, like chrysanthemums, roses, and carnations, are very heterozygous or polyploid. This makes it hard to fix helpful alleles and guess how complex traits like drought tolerance will separate without big populations and trials in different environments. Also, breeders need to find a balance between durability and beauty. For example, alleles that make plants better able to handle stress by slowing down shoot growth or changing the shape of leaves may not be good if they hurt the compact, symmetrical shapes that people like to buy. Interactions between genes and the environment, as well as a lack of genomic information, make selection even harder. This has made it very important to have molecular tools that can make specific changes to elite ornamentals without changing their carefully chosen genetic backgrounds.

Overview of CRISPR/Cas genome editing in plants

CRISPR/Cas systems, which are based on bacterial adaptive immunity, use a guide RNA (gRNA) to send a nuclease, like Cas9 or Cas12a, to a complementary DNA sequence, where it makes a double-strand break. Homology-directed repair (HDR) lets you replace or add exact sequences when you have a donor template. Non-homologous end joining (NHEJ) repair, on the other hand, can break genes by making small insertions or deletions. Base editors catalyze specific nucleotide conversions without inducing double-strand breaks, while prime editors integrate reverse transcriptase with Cas nickases to effectuate versatile minor modifications. Agrobacterium tumefaciens-mediated transformation, particle bombardment, or temporary methods like protoplast transfection and viral vectors are the most common ways to get CRISPR reagents into plants. One of the biggest problems with many ornamental plants is still getting whole plants to grow back from changed tissues. Nonetheless, successful gene editing has been recorded in several ornamental flowers, such as petunia, torenia, chrysanthemum, carnation, lily, gentian, and additional species. Aside from basic gene knockouts, multiplex CRISPR can also target several homoeologs in polyploid ornamentals at the same time. This is important for changing traits that are controlled by duplicate gene families in roses and chrysanthemums. Base and prime editors greatly expand the design area by letting you make small changes to protein function or regulatory patterns related to stress responses without adding foreign DNA.

Current status of CRISPR applications in ornamental flowers

Editing proof-of-concept and visual indicators

Editing the phytoene desaturase (PDS) gene in petunias (Petunia × hybrida) caused albino phenotypes and proved effective targeted mutagenesis, one of the first examples of CRISPR effectiveness in ornamentals. Genes involved in carotenoid or flavonoid production pathways have been used to create comparable visual marker systems in torenia and lilies. These proof-of-concept research produced crucial factors that now support more complex trait editing in ornamental species, including transformation techniques, promoter selections, and gRNA design guidelines.

Color and shape of flowers

The most sophisticated use of CRISPR in ornamentals is yet flower color manipulation. By interfering with anthocyanin production, CRISPR/Cas9-induced flavanone 3-hydroxylase (F3H) knockout in Torenia provideeri changed the flower's hue from light blue to white. A glutathione transferase gene involved in anthocyanin transport was edited in Japanese gentian to produce lines with white or light blue blooms. Mutations in PDS caused unique light yellow or albino phenotypes in lilies. By focusing on FLOWERING LOCUS T (FT) and TERMINAL FLOWER 1 (TFL1) homologs, CRISPR has also been used to modify petunia flowering duration and plant architecture, offering more tools to align flowering with market windows or particular climate conditions.

Senescence and flower longevity

Environmental factors have a significant impact on flower lifetime, which is essential to decorative value. CRISPR has been utilized to control autophagy, ethylene biosynthesis, signaling, and senescence. When 1-aminocyclopropane-1-carboxylate oxidase genes (PhACO3 and PhACO4) were edited in petunia cv. "Mirage Rose," ethylene production was decreased and blossom life was greatly increased. The simultaneous roles of autophagy and ethylene in controlling floral longevity, on the other hand, were shown by the accelerated petal senescence caused by CRISPR/Cas9-mediated mutation of autophagy-related gene 6 (PhATG6). These discoveries provide crucial evidence that CRISPR may be used to modify floral lifespan pathways, which are essential for preserving aesthetic quality in the face of heat, drought, and postharvest stress.

New developments in carnations, chrysanthemums, and other

Chrysanthemums' polyploid genome makes genome editing difficult, although advancements are being made. High-value CRISPR targets for creating cold-tolerant cultivars have been suggested by cold-tolerance research that have found transcription factors and antisense RNAs that affect low-temperature responses. (Chesci) In order to delay senescence and perhaps provide stress-resilient vaselife, CRISPR is being investigated to alter the genes involved in ethylene production in carnations, another important cut flower. The same methods and gene families overlap heavily with climate-related stress pathways, putting ornamental plants on the verge of intentional climate-resilience engineering, even though many of these initiatives still concentrate on aesthetic or postharvest features.

Target traits and gene candidates for climate-resilient ornamentals

Tolerance for salinity and drought

The polygenic features of drought and salinity tolerance include downstream effectors, perception, and signaling. Key genes that control ABA signaling, root architecture, ion transport, osmotic adjustment, and stomatal behavior have been found via extensive CRISPR research in crops. For example, mutations in negative regulators of ABA signaling enhanced drought tolerance in rice, whereas editing OsRR22 and OsPRP1 enhanced salinity and cold tolerance, respectively. Similar networks controlling salinity and drought responses are found in ornamentals, according to physiological and transcriptome research. (s) The following are potential CRISPR editing targets: • ABA signaling components, including SnRK2 kinases and protein phosphatases (PP2Cs), where partial knockdown of negative regulators might improve stress response without significantly impairing growth.

- Ion transporters (HKT, NHX, SOS family) regulate the balance of Na and K in salinity; modifying regulatory elements or promoter regions may alter tissue-specific expression to limit the buildup of sodium in leaves and flowers.
- Water absorption efficiency is controlled by aquaporins and root development genes; modest modification of these genes may aid ornamentals in maintaining turgor and bloom size during brief dry periods.
- Transcription factors that coordinate downstream stress responses include DREB/CBF, NAC, and members of the bZIP family. Through promoter editing as opposed to total knockouts, CRISPR has been used in some crops to modify stress-responsive transcription factors to increase tolerance while reducing pleiotropic effects.
- Targeting regulatory areas for "tuning" rather than completely deleting these genes is a realistic approach for ornamental flowers, looking for variations that improve stress tolerance while maintaining the decorative phenotype. This method works especially well for base editors and prime editors.

Tolerance for heat and cold stress

Heat waves are occurring more often and average temperatures are rising due to climate change. Heat-stress-related genes, including as heat shock proteins, membrane-associated transcription factors, and regulators of ROS homeostasis, have been discovered via CRISPR research in rice and other crops. Important nodes in thermotolerance networks have been identified by editing of OsNTL3, OSHSP60-3B, and genes governing leaf shape. In order to prolong growth seasons and guarantee steady blooming in a variety of climates, ornamentals must be able to withstand both cold and heat. In order to improve low-temperature tolerance, cold-responsive genes including CBF/DREB transcription factors, ICE1 analogs, and their downstream COR genes have previously been transgenically altered in chrysanthemum; CRISPR now allows for more accurate editing of these pathways. (Chesci)

CRISPR may be used in future research to:

- Modify heat-shock transcription factor promoters to increase but temporally limit their induction during heat waves.
- Modify the threshold and kinetics of cold acclimation by engineering regulatory motifs in cold-responsive genes, which will lessen frost damage to ornamentals that bloom in the winter.
- To improve resistance to oxidative stress during temperature extremes, target ROS-scavenging enzymes (such as SOD, APX, and CAT).

Stress-stable quality and flower lifetime

Since longer-lasting flowers can better tolerate transportation, temperature changes, and humidity variations while maintaining quality requirements, they are naturally a "climate resilience" characteristic. As was previously mentioned, CRISPR modification of ethylene biosynthesis and perception has expanded the floral longevity of petunias and is now being investigated in carnations and other species.

- Ethylene receptors and signal transducers (ETR, EIN2, EIN3/EIL), where precise editing may desensitize flowers to stress-induced ethylene surges without totally eliminating ethylene sensitivity required for normal growth, are additional climate-relevant targets.
- Under drought or heat, autophagy components (ATGs) that control nutrient recycling may be subtly modulated to balance senescence and survival in petals.
- Expandins, pectinases, and xylanases are cell wall remodeling enzymes that contribute to petal wilting; modifying regulatory areas may reduce the rate at which petals mechanically collapse under low water potential.
- Genes governing vacuolar pH and pigment stability, which impact color fading in hotter areas or under intense light; little adjustments may preserve vivid hues even in hotter regions.
- Combinations of ethylene, ABA, and autophagy network modifications may result in cultivars with improved stress tolerance and postharvest lifespan since senescence pathways and abiotic stress responses have a high intersection.

Resistance to pests and diseases in a changing environment

The distribution and phenology of diseases and insect pests that target ornamental flowers are changing due to warming temperatures and changed precipitation patterns. In ornamentals, where comparable pathogen interactions take place, CRISPR-mediated disease resistance—which has been extensively studied in crops (e.g., altering susceptibility genes like MLO or eIF4E)—can be used. Disruption of host susceptibility genes necessary for infection by rusts, powdery mildew, or viral infections prevalent in ornamentals are examples of potential tactics.

- Modifying R-gene regulatory regions to increase or maintain disease resistance without compromising fitness.
- Changing trichome and cuticular wax characteristics that affect insect oviposition and feeding while preserving the desired gloss and texture of leaves.
- CRISPR research in ornamental flowers has not yet focused much on disease resistance, but as pest pressures increase, combining it with climate-oriented breeding will be crucial.

Enabling technologies: transformation, regeneration and omics

For many ornamentals, effective transformation and plant regeneration continue to be major obstacles to using CRISPR. Petunia, chrysanthemum, carnation, gerbera, and a number of lilies have protocols that are becoming more widely accessible, but significant genera still lack reliable methods. Advances in tissue culture, morphogenic regulators, and ornamental genotypes that promote regeneration are highlighted in recent studies. Resources for multi-omics are growing quickly. Transcriptome datasets under drought, salinity, and temperature stress are being created and made publically accessible, along with de novo genome assemblies for ornamental plants such as roses, chrysanthemums, carnations, marigolds, and others. These tools make it possible to:

- Identify genes that respond to stress and ornamental-specific regulatory networks.
- Identification of gene families unique to ornamentals that might be modified to increase resilience without sacrificing distinctive floral characteristics.
- The creation of gRNAs in polyploid ornamentals that target many homoeologs.
- It will be particularly beneficial to combine phenomics (such as high-throughput imaging of leaf temperature, color, and wilting) with omics-based gene identification to analyze complicated qualities like "maintained visual quality" under varying stress.

Biosafety, regulatory and socio-economic considerations

Different nations have different laws governing genome-edited ornamentals. While some countries regulate all kinds of genome editing identically to transgenics, others exclude products of simple gene knockouts without foreign DNA from GMO restrictions. The risk evaluation for ornamentals is less concerned with food safety and more with environmental effects, such as invasiveness or gene flow to wild cousins. Socioeconomically speaking, ornamentals provide both chances and difficulties for the application of CRISPR:

- Possibilities: Unlike edible crops, ornamentals are usually eaten aesthetically rather than as food, which may allay consumer worries.
- New colors, forms, and longer vase lives are rewarded by the market, which may encourage the adoption of modified cultivars that also possess "hidden" resilience features.
- Difficulties: o Breeders must negotiate the strictest regulatory frameworks among trade partners since many ornamental markets are export-focused.
- Small and medium-sized breeders may face obstacles due to proprietary CRISPR technology and freedom-to-operate issues.
- Building public confidence and distinguishing genome-edited ornamentals from conventional GMOs and conventionally cultivated cultivars need clear labeling and communication.

Future perspectives and conclusions

The convergence of climate change, expanding genomic resources and rapid progress in genome editing has created a unique moment for ornamental flower breeding. Evidence from petunia, torenia, chrysanthemum, carnation, lily, gentian and other species shows that CRISPR can be efficiently deployed to manipulate traits directly visible to breeders and consumers—color, form and longevity.() At the same time, a large and growing body of CRISPR research in staple crops has mapped key genes and regulatory hubs underpinning tolerance to drought, salinity, temperature extremes and diseases.()

The challenge and opportunity for the next decade is to bridge these two domains:

1. **Translate stress-tolerance genes and strategies from crops to ornamentals**, prioritizing conserved pathways (ABA, ethylene, ROS, ion homeostasis) while accounting for species-specific sensitivities and aesthetic constraints.
2. **Leverage advanced CRISPR tools**—multiplex editing, base and prime editing, cis-regulatory editing—to fine-tune stress responses without compromising ornamental quality.
3. **Invest in transformation and regeneration pipelines** for recalcitrant ornamental genera, using morphogenic regulators and genotype-independent approaches where possible.
4. **Integrate multi-omics, phenomics and machine learning** to identify climate-resilience ideotypes that combine visual appeal with robust performance under variable environments.
5. **Develop clear and proportionate regulatory frameworks**, along with transparent communication strategies, to facilitate responsible commercialization of genome-edited ornamentals.

References

1. Kishi-Kaboshi M, Aida R, Sasaki K. 2018. Genome engineering in ornamental plants: Current status and future prospects. *Plant Physiology and Biochemistry* 131:47–52. doi:10.1016/j.plaphy.2018.03.015.
2. Mekapogu M, Song HY, Lim SH, Jung JA. 2023. Genetic engineering and genome editing advances to enhance floral attributes in ornamental plants: An update. *Plants* 12:3983.()
3. Din A, et al. 2025. Post-genomic era of CRISPR/Cas technology in ornamental plants. *Ornamental Plant Research* (early access).
4. Azadi P, Bagheri H, Nalousi AM, Nazari F, Chandler SF. 2016. Current status and biotechnological advances in genetic engineering of ornamental plants. *Biotechnology Advances* 34:1073–1090.
5. Jin C, et al. 2023. Creating novel ornamentals via new strategies in the era of climate change. *s in Plant Science* 14:1142866.

6. Partap M, et al. 2023. Designing of future ornamental crops: A biotechnological perspective. *Horticulture Research* 10:uhad192.(OUP Academic)
7. Zhang B, Yang X, Yang C, Li M, Guo Y. 2016. Exploiting the CRISPR/Cas9 system for targeted genome editing in petunia. *Scientific Reports* 6:20315.
8. Nishihara M, Higuchi A, Watanabe A, Tasaki K. 2018. Application of the CRISPR/Cas9 system for modification of flower color in *Torenia fournieri*. *BMC Plant Biology* 18:331.(BioMed Central)
9. Shibuya K, et al. 2025. CRISPR/Cas9-mediated *LhNAP* mutagenesis extends flower longevity in lily. *Plant Science* (in press).
10. Mircea DM, et al. 2024. Abiotic stress tolerance and invasive potential of ornamental plants in Mediterranean environments. *Agronomy* 15:52.