AgriScope
Monthly e-Magazine on Agriculture and Interdisciplinary Sciences
Visit at us: www.agriscope.in
Email at us: agri4scope@gmail.com

CRISPR-Driven Innovations in Horticulture: Bridging Molecular Genetics, Post-Harvest Physiology and Insect Ecology

Arti Devi[1*], Sejal Thakur[2], Sejal[3], Vanshika[2] and Shreya[4]

[1]M.Sc. Student, Department of Basic Sciences, COHF, Neri, Dr. YSPUHF, Nauni, Solan, Himachal Pradesh, India
[2]M.Sc. Student, Department of Entomology, COHF, Neri, Dr. YSPUHF, Nauni, Solan, Himachal Pradesh, India
[3]M.Sc. Student, Department of Food Science and Technology, COHF, Neri, Dr. YSPUHF, Nauni, Solan, Himachal Pradesh, India
[4]M.Sc. Student, Department of Vegetable Sciences, COHF, Neri, Dr. YSPUHF, Nauni, Solan, Himachal Pradesh, India
[1*]Corresponding author email - artidevi2842004@gmail.com

Article ID: 24003

1. Introduction

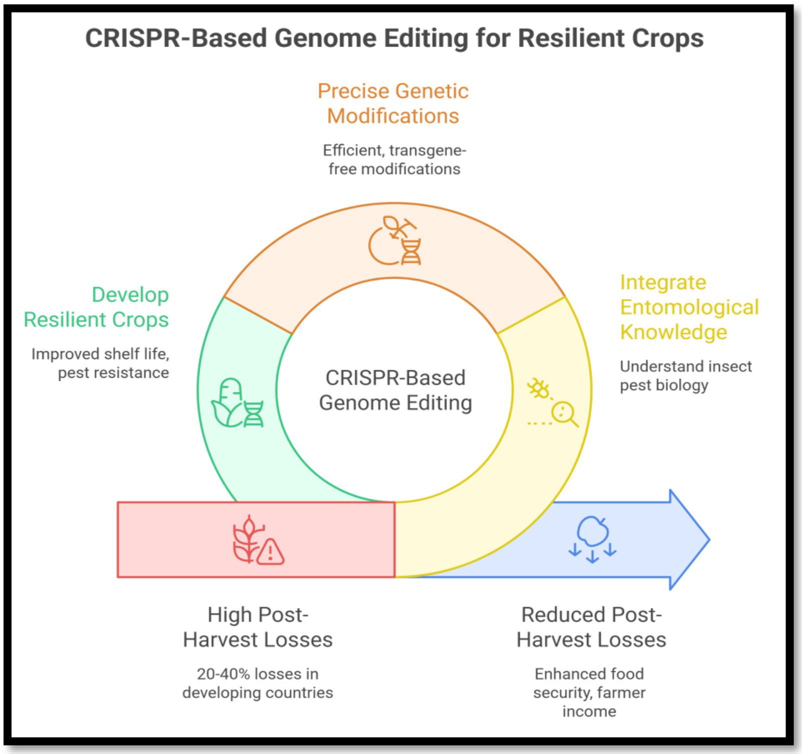


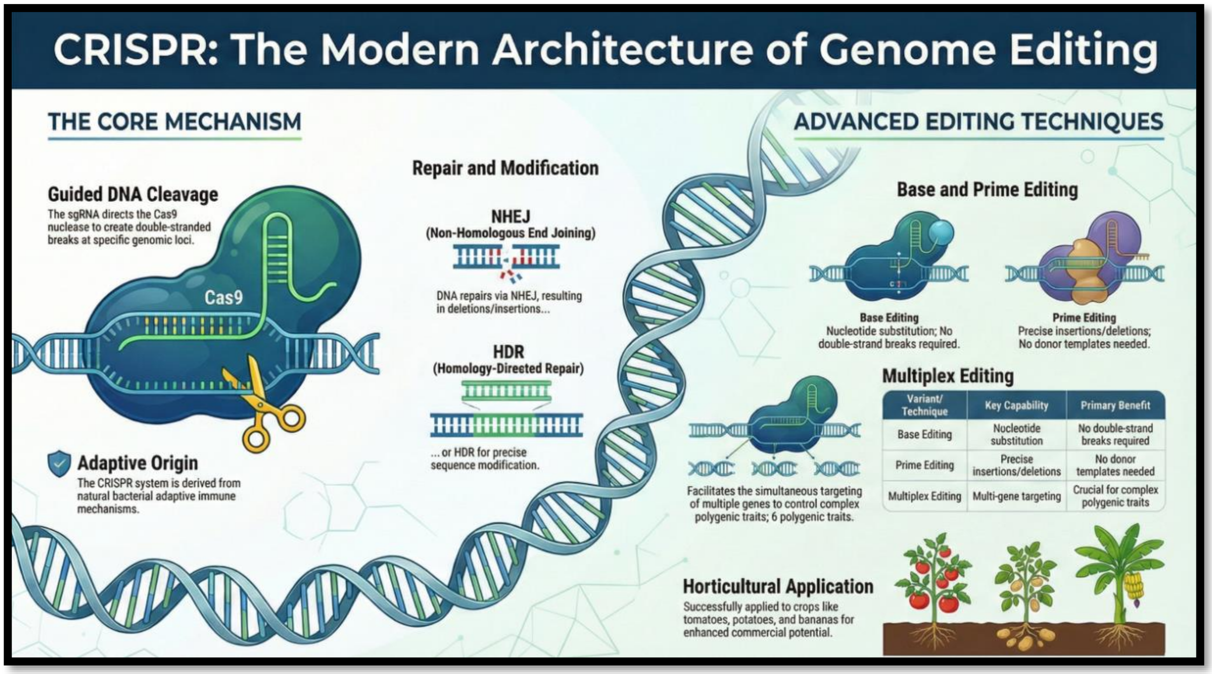
Figure 1: CRISPR- Based Genome Editing for Resilient Crops

Horticultural crops are key sources of vitamins and micronutrients, yet **20–40% of fruits and vegetables are lost post-harvest** in developing countries due to physiological deterioration, microbial spoilage, mechanical damage and insect pests (FAO). Processes such as respiration, ethylene production and oxidative stress accelerate ripening in climacteric fruits like tomato, banana and mango, while pests further increase losses by promoting infections (Savary et al., 2019). Conventional breeding for delayed ripening and pest resistance is slow and transgenic crops like *Solanum lycopersicum* **Flavr Savr** faced public concerns. **CRISPR-Cas**

genome editing offers a precise approach to improve shelf life and insect resistance in horticultural crops (Jaganathan et al., 2018).

2. CRISPR-Cas Genome Editing

CRISPR, derived from bacterial immune systems, uses **Cas9** guided by sgRNA to create targeted DNA double-strand breaks. These are repaired by **NHEJ**, causing insertions/deletions or **HDR**, enabling precise genome modification (Bortesi & Fischer, 2015).



The sgRNA directs the Cas9 nuclease to create double-stranded breaks at specific genomic loci.

The CRISPR system is derived from natural bacterial adaptive immune mechanisms.

DNA repairs via NHEJ, resulting in deletions/insertions...

... or HDR for precise sequence modification.

Base Editing: Nucleotide substitution; No double-strand breaks required.

Prime Editing: Precise insertions/deletions; No donor templates needed.

Facilitates the simultaneous targeting of multiple genes to control complex polygenic traits; 6 polygenic traits.

Variant/ Technique	Key Capability	Primary Benefit
Base Editing	Nucleotide substitution	No double-strand breaks required
Prime Editing	Precise insertions/deletions	No donor templates needed
Multiplex Editing	Multi-gene targeting	Crucial for complex polygenic traits

Successfully applied to crops like tomatoes, potatoes, and bananas for enhanced commercial potential.

Figure 2: CRISPR-Cas Genome Editing

The most widely used CRISPR system is **SpCas9** from *Streptococcus pyogenes*, though variants like **Cas12a (Cpf1)** and **Cas13** have expanded editing capabilities.

- **Base Editing**: for single nucleotide changes (Komor et al. 2016).
- **Prime Editing**: for precise insertions, deletions and substitutions (Anzalone et al. 2019).
- **Multiplex Editing**: to target multiple genes simultaneously (Zhang et al. 2020).

3. Entomological Perspectives in Crop Improvement

3.1 Insect-Induced Pre and Post-Harvest Losses

Insect pests such as *Helicoverpa armigera*, aphids, thrips, whiteflies and *Sitophilus* spp. cause major losses in horticultural crops and increase fungal infections. Climate change further intensifies pest pressure (Deutsch et al., 2018), making stronger plant resistance essential.

3.2 Molecular Basis of Plant- Insect Interactions

Plants resist herbivorous insects through **structural barriers**, **defence signalling pathways** (JA, SA, ethylene) and **defensive metabolites and proteins**. The **jasmonic acid pathway** is central to this defence and CRISPR editing of its regulatory genes can enhance resistance without introducing foreign DNA (Howe & Jander, 2008).

4. CRISPR Applications in Insect Resistance

4.1 Editing Susceptibility (S) Genes

Certain plant susceptibility genes facilitate insect feeding or pathogen entry. Editing genes involved in cell wall loosening or nutrient transport can limit pest access to nutrients. For example, CRISPR-mediated mutation of **SWEET** sugar transporter genes enhances resistance to pathogens (Chen et al., 2019).

4.2 Enhancement of Defensive Compounds

CRISPR can enhance insect resistance by upregulating genes involved in insecticidal metabolite production. Editing terpene synthase genes may increase volatile compounds that repel herbivores or attract natural enemies, strengthening plant–insect–natural enemy interactions and supporting integrated pest management (IPM).

4.3 Gene Editing in Insect Populations

CRISPR can modify insect genomes to suppress pests through gene drives or fertility gene editing (Esvelt et al., 2014). However, potential ecological risks require careful regulation.

5. CRISPR in Post-Harvest Quality Improvement

5.1 Modification of Cell Wall Degradation

Fruit softening is driven by enzymes such as **polygalacturonase (PG)**, **pectate lyase (PL)** and **expansins**. Editing **PG genes** can produce firmer fruits with longer storage life and reduced susceptibility to insect damage and microbial infection (Uluisik et al., 2016).

5.2 Oxidative Stress and Senescence

Accumulation of **reactive oxygen species (ROS)** accelerates senescence. Editing antioxidant enzyme regulators can enhance stress tolerance and extend post-harvest life by reducing storage damage.

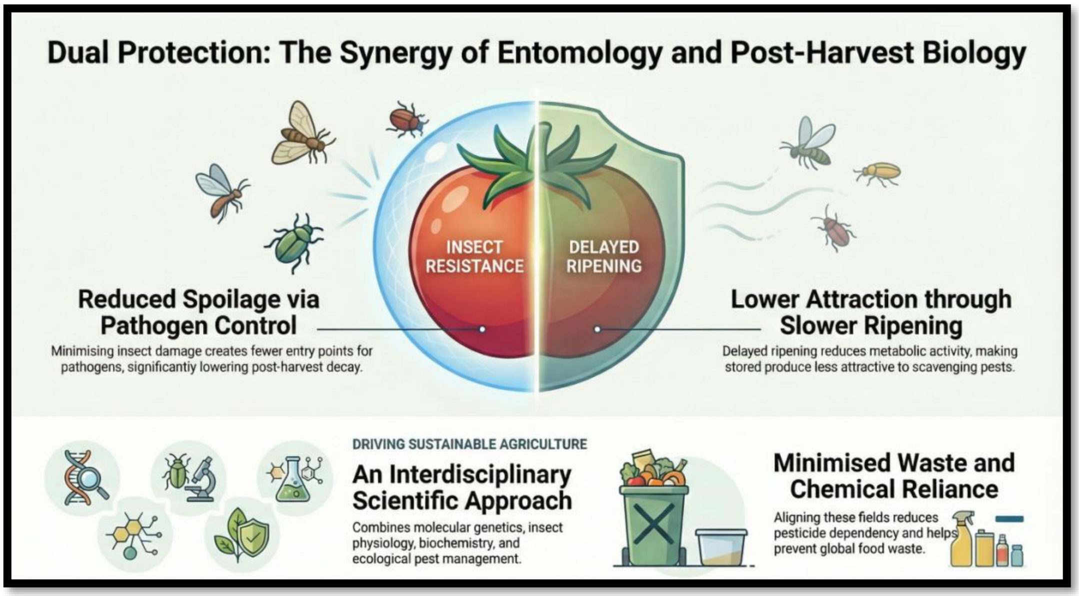
5.3 Case Example: Tomato as a Model Crop

Tomato (*Solanum lycopersicum*) is a key model for CRISPR-based shelf-life improvement. Editing ripening regulators such as **RIN** and **NOR** enables controlled ripening without affecting flavor (Zhang et al., 2020).

6. Integration of Entomology and Post-Harvest Biology

Integrating **insect resistance** with **delayed ripening** offers dual protection by reducing pest damage, pathogen entry and post-harvest spoilage, while slower ripening lowers metabolic activity and pest attraction during storage. This approach combines **molecular genetics, insect physiology, post-harvest biochemistry and ecological pest management**. Such integration aligns with sustainable agriculture goals by reducing pesticide reliance and minimizing food waste.

7. Advantages of CRISPR-Based Integration



Minimising insect damage creates fewer entry points for pathogens, significantiy lowering post-harvest decay.

Delayed ripening reduces metabolic activity, making stored produce less attractive to scavenging pests.

Combines molecular genetics, insect physiology, biochemistry, and ecological pest management.

Aligning these fields reduces pesticide dependency and helps prevent global food waste.

Figure 3: Interdisciplinary approach

- Reduced chemical pesticide usage
- Lower post-harvest losses
- Environmentally sustainable pest management
- Improved farmer profitability
- Enhanced nutritional and market value

Compared with conventional breeding, CRISPR significantly reduces time required for cultivar development (Jaganathan et al. 2018).

8. Challenges and Ethical Considerations

Despite its potential, CRISPR faces challenges including **off-target mutations**, **polygenic complexity of insect resistance**, **ecological concerns (especially gene drives)**, **varying global regulations** and **public acceptance**. Therefore, transparent risk assessment and stakeholder engagement are essential for responsible deployment.

9. Future Prospects

Future research should focus on:

- Integration with genomics, transcriptomics, proteomics and metabolomics.
- Precision editing for improved tritrophic interactions.
- Climate-resilient pest-resistant cultivars.
- CRISPR-based epigenome editing.
- Sustainable insect population management.

The convergence of genome editing and applied entomology is poised to transform horticultural crop protection and post-harvest management.

10. Conclusion

CRISPR-based genome editing represents a transformative technology in horticulture. By integrating post-harvest biological insights with entomological innovations, it is possible to develop crops that resist insect attack while maintaining extended shelf life. This dual strategy reduces chemical inputs, minimizes food losses and promotes sustainable agricultural systems. Continued interdisciplinary research, ethical governance and public engagement will determine the success of CRISPR-driven innovations in global horticulture.

References

1. Anzalone AV, Randolph PB, Davis JR, Sousa AA, Koblan LW, Levy JM and Liu DR. 2019. Search- and- replace genome editing without double-strand breaks or donor DNA. *Nature* 576(7785): 149-157.
2. Bortesi L and Fischer R. 2015. The CRISPR/ Cas9 system for plant genome editing and beyond. *Biotechnology advances* 33(1): 41-52.
3. Deutsch CA, Tewksbury JJ, Tigchelaar M, Battisti DS, Merrill SC, Huey RB and Naylor RL. 2018. Increase in crop losses to insect pests in a warming climate. *Science* 361(6405): 916-919.
4. Esvelt KM, Smidler AL, Catteruccia F and Church GM. 2014. Concerning RNA-guided gene drives for the alteration of wild populations. *elife* 3: e03401.
5. Howe GA and Jander G. 2008. Plant immunity to insect herbivores. *Annual Review of Plant Biology* 59: 41–66.
6. Jaganathan D, Ramasamy K, Sellamuthu G, Jayabalan S and Venkataraman G. 2018. CRISPR for crop improvement: an update review. *Frontiers in plant science* 9: 985.

7. Komor AC, Kim YB, Packer MS, Zuris JA and Liu DR. 2016. Programmable editing of a target base in genomic DNA without double-stranded DNA cleavage. *Nature* 533(7603): 420-424.
8. Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N and Nelson A. 2019. The global burden of pathogens and pests on major food crops. *Nature ecology & evolution* 3(3): 430-439.
9. Uluisik S, Chapman NH, Smith R, Poole M, Adams G, Gillis RB and Seymour GB. 2016. Genetic improvement of tomato by targeted control of fruit softening. *Nature biotechnology* 34(9): 950-952.
10. Zhang Y, Massel K, Godwin ID amd Gao C. 2018. Applications and potential of genome editing in crop improvement. *Genome biology* 19(1): 210.