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India Biotech Revolution: The Approval of Genome-Edited Rice

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ABSTRACT

India has reached a significant global milestone by becoming the first country to approve genome-edited rice cultivars for commercial use. The newly introduced varieties, DRR Dhan 100 (Kamala) and Pusa DST Rice 1, developed through advanced genome editing technologies, offer notable improvements in yield and climate resilience. DRR Dhan 100 matures faster and delivers a 25% increase in yield, while Pusa DST Rice 1 boosts productivity by up to 30% in saline and alkaline soils. Tailored for cultivation in regions such as Andhra Pradesh and Telangana, these breakthroughs mark a major step forward in promoting climate-smart agriculture and sustainable rice production in India.

INTRODUCTION

Rice (*Oryza sativa L.*) is a cornerstone of global food security, feeding more than half of the world's population and playing a vital role in the cultural and economic fabric of many countries, especially across Asia [1]. However, rice cultivation is facing mounting challenges. The need to increase yields, improve nutritional quality, and enhance resilience to pests, diseases, drought, salinity, and the growing impacts of climate change has never been more urgent [2]. While traditional breeding methods have driven significant progress in the past, they are often slow and limited by the narrow genetic diversity available within the crop. Recent breakthroughs in molecular biology are reshaping the future of crop improvement. Among the most exciting developments is genome editing a revolutionary approach in plant science. Unlike earlier genetic engineering techniques that involved introducing foreign DNA, genome editing allows for precise modifications to the plant's own genome. This not only marks a significant technical shift but also influences how such crops are regulated and received by the public. In many cases, genome-edited plants are not subject to the same strict oversight as conventional genetically modified organisms (GMOs) [3]. Leading the way in genome editing is the CRISPR-Cas system, a powerful tool that acts like molecular scissors, cutting DNA at exact locations. After the cut, the plant's natural repair mechanisms kick in, either disabling specific genes or incorporating beneficial genetic changes. Because of its precision, efficiency, and flexibility, CRISPR-Cas has quickly become the preferred tool for plant genome editing with rice research at the forefront of this scientific transformation [4].

India, one of the world's largest rice producers and consumers, has reached a major milestone in agricultural advancement with the approval of its first genome-edited rice varieties DRR Dhan 100 (Kamala) and Pusa DST Rice 1. This landmark move signals a significant shift in the country's approach to crop development, embracing cutting-edge biotechnology to address longstanding challenges. As reported by The Economic Times [5], these new varieties are expected to boost rice yields by 20-30% and significantly lower water requirements, offering a promising path toward improved productivity and sustainability. This development not only enhances the efficiency of rice cultivation but also reinforces India's commitment to long-term food security. The development of DRR Dhan 100 (Kamala) and Pusa DST Rice 1 was made possible through the use of CRISPR-Cas technology, which enables precise edits to the plant's native genome. As noted by the Indian Council of Agricultural Research [6], this method allows scientists to make targeted genetic changes without inserting any foreign DNA. This key distinction sets genome editing apart from conventional genetic modification and significantly influences how such crops are regulated. In India, genome-edited varieties that do not involve transgenic material follow a streamlined regulatory pathway, allowing for quicker and more efficient approval compared to genetically modified (GM) crops.

ICAR has ushered in a significant advancement for Indian agriculture with the development of the nation's first genome-edited rice varieties: DRR Rice 100 (Kamla) and Pusa DST Rice 1. These pioneering varieties, engineered using CRISPR-Cas technology for higher yields, climate resilience, and water conservation, promise revolutionary changes. The precise genome editing, involving SDN 1 and SDN 2 genes without introducing foreign DNA, has been approved under India's biosafety regulations for general crops. This breakthrough is the culmination of ICAR's genome-editing research, initiated in 2018 under the National Agricultural Science Fund to improve Samba Mahsuri and MTU 1010, and offers substantial benefits including a 19% yield increase, a 20% reduction in greenhouse gas emissions, a saving of 7,500 million cubic meters of irrigation water, and improved tolerance to drought, salinity, and other climate stresses. ICAR-IIRR in Hyderabad developed DRR Rice 100 (Kamala), a genome-edited version of Samba Mahsuri (BPT 5204). This variety matures about 20 days earlier (around 130 days) and is engineered for more grains per panicle. This faster growth reduces water and fertilizer needs, lowers methane emissions, and its strong stalk resists lodging. The grain quality is similar to the widely favored Samba Mahsuri. Pusa DST Rice 1, from ICAR-IARI, New Delhi, is another genome-edited variety, derived from MTU 1010. It demonstrates significant yield increases (9.66% to 30.4%) in salt-affected soils, with a potential overall yield boost of up to 20%. These improved rice varieties are intended for broad adoption across India, including Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Puducherry, Kerala, Chhattisgarh, Maharashtra, Madhya Pradesh, Odisha, Jharkhand, Bihar, Uttar Pradesh, and West Bengal. The introduction of these genome-edited rice varieties marks significant advancement towards India's developed nation goals and the promotion of sustainable agriculture. This commitment is supported by the Indian government's allocation of ₹500 crores in the 2023-24 budget for genome editing in crops, with ICAR already expanding this research to oilseeds and pulses [7].

This paper provides an in-depth evaluation of genome editing in rice breeding, with a specific focus on the development and implications of India's newly approved varieties. It examines the scientific principles of genome editing, the enhanced traits of DRR Dhan 100 (Kamala) and Pusa DST Rice 1, their potential benefits and risks, and the evolving regulatory landscape for genome-edited crops in India and globally. By synthesizing current knowledge and addressing critical questions, this study aims to advance the understanding of genome editing's role in shaping the future of rice agriculture and food security in India and beyond (Fig .1).

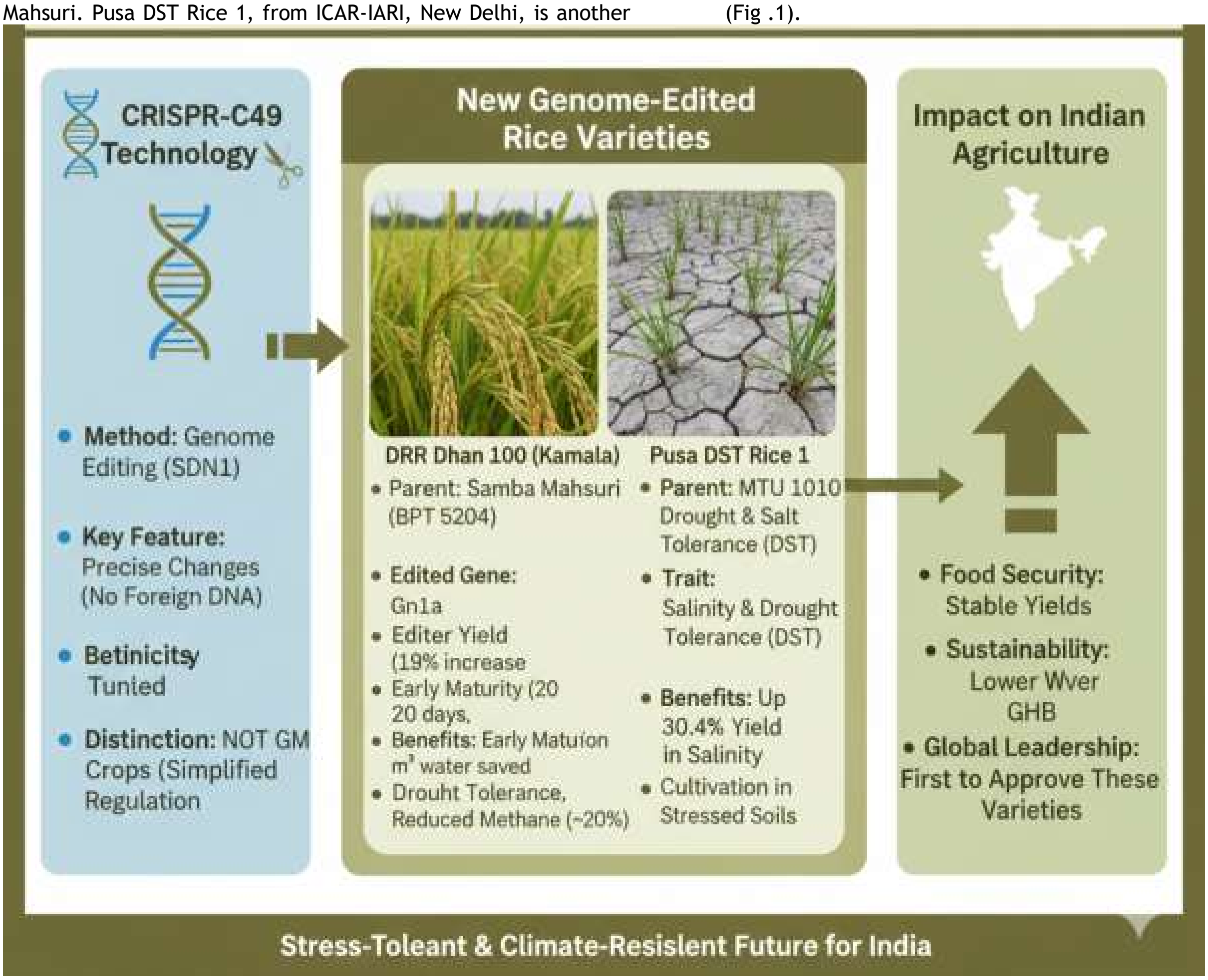

Fig. 1: Biotech Revolution Genome-Edited Rice

Meet the Two New Climate-Smart Rice Varieties

DRR Dhan 100 (Kamala)

Yield Advantage: Achieves up to 25% higher yields compared to traditional rice varieties.

Early Maturation: Its shorter growth cycle allows farmers the potential for multiple harvests within a single year.

Resource Efficiency: Bred for enhanced productivity while efficiently utilizing natural resources.

Ideal Growing Zones: Recommended for cultivation in Andhra Pradesh, Telangana, and similar agro-climatic regions.

Key Benefits: This variety is particularly advantageous in areas where early harvesting and rapid crop rotation are crucial. Its vigorous growth makes it a preferred choice for maximizing land utilization and increasing annual farm income.

Pusa DST Rice 1

Key Advantage: Its inherent resistance to salinity and alkalinity makes it an excellent choice for degraded or coastal farmlands.

Improved Yields: Shows a significant yield increase of up to 30% in saline soils.

Adaptability to Climate: Bred to withstand the challenges of erratic monsoons and water scarcity common in India.

Recommended Regions: Particularly beneficial for coastal and salt-affected agricultural zones where conventional rice varieties struggle to produce viable harvests.

Impact: Pusa DST Rice 1 offers a promising solution for Indian farmers cultivating in areas afflicted by salt-induced soil degradation, a widespread issue impacting millions of hectares.
The table 1 presents two improved rice varieties DRR Dhan 100 (Kamala) and Pusa DST Rice 1 highlighting their key genetic traits and regions of adoption. DRR Dhan 100 (Kamala) is a high-yielding, semi-dwarf variety with resistance to bacterial leaf blight, making it ideal for irrigated regions in southern Indian states such as Andhra Pradesh, Telangana, Tamil Nadu, and Karnataka. In contrast, Pusa DST Rice 1, bred from the widely cultivated Pusa 44, is drought-tolerant, early-maturing, and offers superior grain quality. It is specifically suited for rainfed areas in Eastern India, including Bihar, Jharkhand, and Eastern Uttar Pradesh, where limited water availability often hampers rice production.

Table 1: Genetic Traits and Adoption Regions of DRR Rice Varieties Dhan 100 (Kamala) and Pusa DST Rice 1

Rice Variety	Genetic Traits	Region(s) of Adoption
DRR Dhan 100 (Kamala)	- High yielding - Semi-dwarf plant type - Resistant to bacterial leaf blight (BLB) - Suitable for irrigated ecosystems	Andhra Pradesh, Telangana, Tamil Nadu, Karnataka
Pusa DST Rice 1	- Drought-tolerant - Derived from Pusa 44 background - Early maturing- High grain quality	Rainfed areas in Eastern India (e.g., Bihar, Jharkhand, Eastern UP)

Precision edits
IARI's Pusa Rice DST1 exhibits improved tolerance to both drought and salinity. Scientists at the institute used gene knockout to inactivate a gene that suppresses stress resistance mechanisms. This genetic modification led to rice plants with fewer stomata (reducing water loss), increased tiller production, higher grain yields, and better survival in saline soils. Field evaluations in India showed that Pusa Rice DST1 significantly outperformed its parent variety, MTU1010, under water scarcity and high salt concentrations. Meanwhile, IIRR developed DRR Dhan 100, specifically targeting the widely grown Samba Mahsuri variety. By applying CRISPR gene editing to a cytokinin oxidase gene (*OsCKX2*), the researchers created a new genetic variant. This resulted in a 19% increase in grain yield, a faster maturation period of up to 20 days, and enhanced growth even with limited fertilizer and under drought conditions. Dr. Varshney emphasized that these enhanced rice varieties, with their superior stress tolerance and productivity, offer promising solutions to mitigate the impacts of climate change and resource limitations for Indian farmers.

CRISPR/Cas9 Based Rice Crop Improvement
The CRISPR/Cas9 genome editing system functions by utilizing the Cas9 nuclease to introduce double-strand breaks (DSBs) in DNA at specific sites, guided by a single-guide RNA (sgRNA). These breaks are typically repaired through the non-homologous end joining (NHEJ) pathway, which often results in insertions or deletions (indels) at the targeted locus, effectively disrupting the function of the gene [8]. Among genome editing technologies, CRISPR/Cas9 is the most widely adopted for enhancing key agronomic traits in rice, including grain yield, tolerance to abiotic stresses, resistance to diseases and herbicides, and improved grain quality. Unlike conventional breeding methods which can take 6 to 7 years to achieve the desired level of homozygosity CRISPR/Cas9 can accomplish this within a single year, underscoring its role as a groundbreaking tool in modern plant breeding. This article explores the diverse applications of CRISPR/Cas9 in advancing rice cultivation.
In the 1960s, researchers made major strides in crop improvement by modifying genes that regulate plant height in rice and wheat. These changes produced shorter plants with improved resistance to lodging and greater responsiveness to fertilizers key factors that drove a dramatic increase in grain yields. This transformative period in agricultural history is famously known as the Green Revolution [9]. Since then, reshaping rice plant architecture has remained a central focus of breeding programs, with efforts centered on identifying vital quantitative trait loci (QTLs) and utilizing transgene transfer techniques. Today, the advent of CRISPR/Cas9 has revolutionized this area of research. As a precise, efficient, and transgene-free gene-editing system, CRISPR/Cas9 offers a powerful means to modify plant traits. Scientists have successfully used it to edit or knock out genes and QTLs associated with important characteristics like plant height and tiller number. Key targets include *semi-dwarf 1* (SD1) [10], *STRONG CULM3/TEOSINTE BRANCH1/FINE CULM1* (SCM3/OsTB1/FC1) [11], and *Gibberellin-20 oxidase-2* (OsGA20ox2) [12].
Using the CRISPR/Cas9 system to target the ABA receptor gene *Pyrabactin Resistance 9* (*OsPYL9*) has been shown to enhance grain yield in rice [13]. In a similar approach, editing three related genes *PYL1*, *PYL4*, and *PYL6* led to a 31% increase in grain number, resulting in significantly higher yields in mutant plants compared to wild-type lines [14]. These results highlight the promising potential of modifying hormone signaling pathways as a strategic tool to boost crop productivity and strengthen global food security.
Elevated global temperatures are driving global warming, also known as climate change, intensifying drought spells and soil salinization, which in turn imperils crop yields. Rice, especially vulnerable to abiotic stresses throughout its life cycle, is most severely threatened by drought. This heightened susceptibility stems from its high water demand of 3000 L per kg of grain produced, combined with a shallow root system and a thin cuticle, potentially resulting in complete crop failure [15]. Moreover, rice grown in the highlands of countries such as China, Japan, and Korea experiences diminished grain yield and quality due to low temperatures during reproduction. Compared to other cereals like wheat, rice is also more susceptible to salt stress, raising concerns about a potential 50% reduction in global rice production [16]. Tackling these issues is challenging because drought and salinity tolerance are complex traits influenced by a multitude of genes, proteins, transporter proteins, transcription factors (TFs), ion transporters, microRNAs (miRNAs), hormones, metabolites, and ions [17]. Consequently, conventional breeding methods have limited success in accumulating these favorable genes within cultivars to develop stress-tolerant plants. Nevertheless, the CRISPR/Cas9 system, a powerful and versatile gene-editing technology, has been successfully implemented to enhance abiotic stress tolerance in a variety of plant species, including corn, rice, tomato, wheat, *Arabidopsis thaliana*, and *Physcomitrella patens* [18].
Rice grain length and size are crucial visual characteristics that influence consumer preference, with longer grains often being favored. The CRISPR/Cas9 system has been successfully applied to modify the *GS3* (*GRAIN SIZE 3*) gene, leading to an increase in both grain size and length [19]. Recent studies have also demonstrated that CRISPR/Cas9-mediated mutagenesis of three cytochrome P450 genes (Os03g0603100, Os03g0568400, and *GL3.2*) in conjunction with the *OsBADH2* gene can enhance both grain size and fragrance [20]. Additionally, CRISPR-based editing of the *OsFWL4* gene has been shown to significantly increase rice grain length [21], thus boosting consumer acceptance.
Gene editing tools like CRISPR/Cas, TALENs, and ZFNs offer immense and lasting possibilities for transforming a wide range of fields, especially healthcare and agriculture. In recent years, plant gene editing techniques have become widely used across various applications in India and globally, valued for their speed, ease of use, accuracy, and potential cost-effectiveness compared to traditional breeding methods [22].
For instance, CRISPR/Cas-based genome engineering has revolutionized the way desirable traits are introduced and improved in crops, surpassing the limitations of conventional breeding [23]. This technology provides high efficiency and the capability to generate a diverse spectrum of genetic modifications in plants, holding significant promise for enhancing food security and agricultural sustainability in India and beyond.

Researchers have explored multiple avenues to minimize unintended off-target modifications during genome editing. These strategies involve optimizing the guide RNA (sgRNA) sequence for greater precision in targeting, controlling the activity of the Cas9-sgRNA complex to limit its action to the intended site, and employing engineered Cas9 enzymes with enhanced cutting efficiency [24]. Adding to the complexity, many agriculturally significant traits are controlled by multiple genes and are also influenced by environmental conditions. This is true for characteristics like tolerance to environmental stresses (abiotic stresses), yield production, the ability to withstand climate change, and resistance to plant diseases. This complex interplay of genetic and environmental factors presents significant challenges and underscores the need for more in-depth research into plant physiology and genetics to effectively apply gene editing for crop improvement [25]. Moreover, translating the success of genetically modified (GM) crops from the controlled environment of research labs to the widespread adoption in agricultural fields requires careful consideration. Several challenges impede this transition, including navigating legal and regulatory landscapes, addressing public concerns and acceptance, and overcoming existing policy hurdles in India and worldwide. Successfully addressing these limitations is crucial to fully harness the benefits of gene-edited crops for enhancing food security and agricultural sustainability in the face of evolving environmental conditions.

CONCLUSION

A Step Forward for Smart Farming in India

The launch of DRR Dhan 100 (Kamala) and Pusa DST Rice 1 marks a major milestone in Indian agriculture, demonstrating the transformative potential of genome editing in addressing key challenges in food production. With their enhanced yields, environmental resilience, and suitability for diverse growing conditions, these innovative rice varieties offer practical solutions to climate change, soil degradation, and food insecurity. By embracing genome-edited crops, India sets a global precedent, paving the way for broader adoption of agricultural biotechnology and delivering lasting benefits to farmers, consumers, and the nation's food security landscape.

REFERENCES

- Sackey, O. K., Feng, N., Mohammed, Y. Z., Dzou, C. F., Zheng, D., Zhao, L., & Shen, X. (2025). A comprehensive review on rice responses and tolerance to salt stress. *Frontiers in Plant Science*, *16*, 1561280.
- Kumar, N., Chhokar, R. S., Meena, R. P., Kharub, A. S., Gill, S. C., Tripathi, S. C., ... & Singh, G. P. (2021). Challenges and opportunities in productivity and sustainability of rice cultivation system: a critical review in Indian perspective. *Cereal research communications*, 1-29.
- Caradus, J. R. (2023). Processes for regulating genetically modified and gene edited plants. *GM Crops & Food*, *14*(1), 1-41.
- Zegeye, W. A., Tsegaw, M., Zhang, Y., & Cao, L. (2022). CRISPR-based genome editing: advancements and opportunities for rice improvement. *International Journal of Molecular Sciences*, *23*(8), 4454.
- *The Economic Times* https://m.economictimes.com/small-biz/sustainability/indias-first-genome-edited-rice-varieties-will-boost-rice-yields-by-20-30-reduce-water-consumption/articleshow/120897251.cms.
- ICAR, https://icar.org.in/union-agriculture-minister-shri-shivraj-singh-chouhan-announces-two-genome-edited-rice-varieties.
- ICAR-Directorate of Knowledge Management in Agriculture, New Delhi.
- Hussain, B., Lucas, S. J., & Budak, H. (2018). CRISPR/Cas9 in plants: at play in the genome and at work for crop improvement. *Briefings in functional genomics*, *17*(5), 319-328.
- Hussain, B. (2015). Modernization in plant breeding approaches for improving biotic stress resistance in crop plants. *Turkish Journal of Agriculture and Forestry*, *39*(4), 515-530.
- Hu, X., Cui, Y., Dong, G., Feng, A., Wang, D., Zhao, C., ... & Qian, Q. (2019). Using CRISPR-Cas9 to generate semi-dwarf rice lines in elite landraces. *Scientific reports*, *9*(1), 19096.
- Cui, Y., Hu, X., Liang, G., Feng, A., Wang, F., Ruan, S., ... & Qian, Q. (2020). Production of novel beneficial alleles of a rice yield-related QTL by CRISPR/Cas9. *Plant Biotechnology Journal*, *18*(10), 1987.
- Han, Y., Teng, K., Nawaz, G., Feng, X., Usman, B., Wang, X., ... & Li, R. (2019). Generation of semi-dwarf rice (Oryza sativa L.) lines by CRISPR/Cas9-directed mutagenesis of OsGA20ox2 and proteomic analysis of unveiled changes caused by mutations. *3 Biotech*, *9*, 1-17.
- Usman, B., Nawaz, G., Zhao, N., Liao, S., Liu, Y., & Li, R. (2020). Precise editing of the OsPYL9 gene by RNA-guided Cas9 nuclease confers enhanced drought tolerance and grain yield in rice (Oryza sativa L.) by regulating circadian rhythm and abiotic stress responsive proteins. *International journal of molecular sciences*, *21*(21), 7854.
- Miao, C., Xiao, L., Hua, K., Zou, C., Zhao, Y., Bressan, R. A., & Zhu, J. K. (2018). Mutations in a subfamily of abscisic acid receptor genes promote rice growth and productivity. *Proceedings of the National Academy of Sciences*, *115*(23), 6058-6063.
- Oladosu, Y., Rafii, M. Y., Samuel, C., Fatai, A., Magaji, U., Kareem, I., ... & Kolapo, K. (2019). Drought resistance in rice from conventional to molecular breeding: a review. *International journal of molecular sciences*, *20*(14), 3519.
- Ma, N. L., Che Lah, W. A., Abd. Kadir, N., Mustaqim, M., Rahmat, Z., Ahmad, A., ... & Ismail, M. R. (2018). Susceptibility and tolerance of rice crop to salt threat: Physiological and metabolic inspections. *PLoS One*, *13*(2), e0192732.
- Hussain, B., Lucas, S. J., Ozturk, L., & Budak, H. (2017). Mapping QTLs conferring salt tolerance and micronutrient concentrations at seedling stage in wheat. *Scientific reports*, *7*(1), 15662.
- Ahmad, S., Sheng, Z., Jalal, R. S., Tabassum, J., Ahmed, F. K., Hu, S., ... & Tang, S. (2021). CRISPR-Cas technology towards improvement of abiotic stress tolerance in plants. In *CRISPR and RNAi systems* (pp. 755-772). Elsevier.
- Zeng, Y., Wen, J., Zhao, W., Wang, Q., & Huang, W. (2020). Rational improvement of rice yield and cold tolerance by editing the three genes OsPIN5b, GS3, and OsMYB30 with the CRISPR–Cas9 system. *Frontiers in plant science*, *10*, 1663.
- Usman, B., Nawaz, G., Zhao, N., Liu, Y., & Li, R. (2020). Generation of high yielding and fragrant rice (Oryza sativa L.) lines by CRISPR/Cas9 targeted mutagenesis of three homoeologs of cytochrome P450 gene family and OsBADH2 and transcriptome and proteome profiling of revealed changes triggered by mutations. *Plants*, *9*(6), 788.
- Gao, Q., Li, G., Sun, H., Xu, M., Wang, H., Ji, J., ... & Zhao, X. (2020). Targeted mutagenesis of the rice FW 2.2-like gene family using the CRISPR/Cas9 system reveals OsFWL4 as a regulator of tiller number and plant yield in rice. *International journal of molecular sciences*, *21*(3), 809.
- Saini, H., Devrani, A., Synrem, G., & Priyanka. (2025). Application of CRISPR Technology in Plant Improvement: An Update Review. *Advances in Agriculture*, *2025*(1), 4578877.
- Malnoy, M., Viola, R., Jung, M. H., Koo, O. J., Kim, S., Kim, J. S., ... & Nagamangala Kanchiswamy, C. (2016). DNA-free genetically edited grapevine and apple protoplast using CRISPR/Cas9 ribonucleoproteins. *Frontiers in plant science*, *7*, 1904.

- S. W. Cho, S. Kim, Y. Kim, et al., "Analysis of Off-Target Effects of CRISPR/Cas-Derived RNA-Guided Endonucleases and Nickases, " Genome Research 24, no. 1 (2014): 132 –141
- L. Arora and A. Narula, "Gene Editing and Crop Improvement Using CRISPR-Cas9 System, " Frontiers in Plant Science 8 (2017): 1932.