TRENDS IN AGRICULTURE SCIENCE

Popular Article

Vol.3 Issue 04 April 2024, Page: 1736-1741

Revolutionizing Pest Control: The Role of CRISPR in Entomology

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https://doi.org/10.5281/zenodo.11112515

Abstract

This paper emphasises how CRISPR technology in the field of entomology has enabled a paradigm change in pest control. CRISPR emerged as a potent tool for precise genetic manipulation in certain insect populations as previous traditional approaches became less effective. This study investigates the revolutionary uses of CRISPR in the creation of insect-resistant crops, interference with the reproduction of disease vectors and support for biological control tactics. CRISPR offers a sustainable pest management strategy that minimises environmental effects and relies less on chemical pesticides by enabling targeted trait modification in insects. It will add to the continuing conversation about the revolutionary role of CRISPR in transforming entomological methods by addressing ethical issues and possible ecological repercussions.

Keywords: Chemical pesticides, CRISPR, Genetic Engineering, Pest Control, Sustainability

Introduction

Pest management has long been an important component of agriculture and the economy, intending to manage a multitude of insects and other creatures that threaten crops, livestock and human health. Traditional pest management approaches frequently entail the use of chemical pesticides, which, while efficient, have several environmental and health implications (Singh *et al.,* 2022). Pesticide misuse has resulted in the development of resistance in many pest species, necessitating the development of novel and sustainable treatments. The worldwide population has become increasingly conscious of the impact of traditional pest control tactics on ecosystems, non-target species and human health in recent years (Sun *et al.,* 2017). The quest for more ecologically friendly and focused approaches has fueled the development of alternative technologies, with genetic engineering emerging as one of the most promising frontiers.

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology has revolutionised genetic engineering and offers enormous potential for addressing pest management concerns. CRISPR is a precise and efficient gene-editing technique that enables scientists to tweak an organism's DNA with unparalleled precision. CRISPR was discovered as

Published: 21 April. 2024
ISSN: 2583-7850

part of the bacterial immune system and has now been used for a variety of uses, including targeted genome changes in plants and mammals (Vijayreddy, 2023).

CRISPR technology provides the capacity to precisely target and change the genes of insect pests in the field of entomology and pest control. Unlike traditional pesticides, which can harm non-target species and pollute the environment, CRISPR enables for the creation of genetically modified organisms (GMOs) with precise features that can disrupt insect reproductive or survival pathways (Singh *et al.,* 2022). The use of CRISPR in pest control represents a paradigm change away from broad-spectrum chemical interventions and towards a more personalised and sustainable strategy. As we dive deeper into the opportunities and problems of using CRISPR in entomology, it becomes evident that this technology can revolutionise pest population management by providing a more ecologically benign and economically feasible road forward (Medina, 2018).

Understanding CRISPR

CRISPR is a breakthrough gene-editing technique derived from the bacterial immune system. CRISPR is made up of short, partly palindromic repeating DNA sequences interspersed with unique DNA sequences obtained from viruses or other foreign entities (Suresh *et al.,* 2021). These distinct sequences function as a bacterial memory, allowing it to recognise and protect against certain risks.

Mechanism of action

The mode of action of CRISPR is broken down into the following major steps:

Constructing the Guide RNA: Researchers create a synthetic RNA molecule that matches the target DNA sequence they intend to change. This RNA molecule acts as a guide for the Cas9 enzyme, directing it to a specific spot in the genome.

Cas9 Binding: A CRISPR-Cas9 complex is formed by combining the Cas9 enzyme with the guide RNA. This complex then looks for the target DNA sequence in the organism's genome.

Cleavage of DNA: When the CRISPR-Cas9 complex discovers a match, the Cas9 enzyme causes a double-strand break in the DNA at that specific place. This rupture activates the cell's inherent healing processes.

Repair of DNA: Non-homologous end joining (NHEJ) or homology-directed repair (HDR) is used by the cell to repair the cut DNA. NHEJ can cause minor insertions or deletions that affect gene function. In contrast, HDR enables the exact replacement or insertion of genomic material (Vijayreddy, 2023).

CRISPR technology is adaptable and may be utilised in genetic engineering for a variety of purposes. It is capable of deactivating specific genes, inserting new genetic material, regulating gene expression and studying gene function on a massive scale (Zhang *et al.,* 2021). It may also

Published: 21 April. 2024
ISSN: 2583-7850

be used to regulate genes, allowing for the addition of desirable features or the repair of genetic abnormalities. Understanding the principles and processes of CRISPR is critical for realising its potential in sectors like entomology and pest control.

CRISPR in Entomology

A. Targeting Insect Pests

CRISPR technology is a powerful tool in entomology, providing a focused and precise method for managing insect pests that threaten agriculture, ecosystems and public health. It enables unparalleled accuracy in the alteration of insect populations genes, minimising off-target effects and maintaining beneficial insects. CRISPR is frequently used to damage insect pest's reproductive capacity, adding characteristics that lead to population decline over multiple generations. The Sterile Insect Technique (SIT) can be used to produce sterile male insects that mate with wild females, therefore lowering pest populations without the use of chemical pesticides (Singh *et al.,* 2022).

Insecticide resistance is a major issue in pest control and CRISPR offers a fresh method by targeting and changing genes related to resistance mechanisms, perhaps restoring the efficiency of conventional pesticides. CRISPR can also be used to design crops with improved insect resistance, safeguarding crops and lowering dependency on external chemical applications (Lester *et al.,* 2020). Understanding insect biology is critical for CRISPR because it allows the researchers to investigate insect genes on a functional level and change the genomes of model animals for genetic research. CRISPR, on the other hand, may have off-target effects, potentially leading to unexpected consequences. To reduce the possibility of unintended genetic alterations, rigorous testing and validation are required (Banerjee *et al.,* 2023).

B. Precision in Gene Editing

CRISPR is a precision gene editing method with various applications in entomology. It enables scientists to precisely target and edit specific genes inside insect pest genomes, limiting off-target effects and guaranteeing that the required genetic modifications occur only at the intended places. This accuracy is especially useful in pest management, where researchers utilise it for gene knockout, gene insertion and gene regulation (Zhang *et al.,* 2021). The accuracy of CRISPR allows for exact DNA sequence specificity, minimising off-target effects and allowing researchers to fine-tune the activation of certain genes associated with insect growth, reproduction or sensitivity to environmental variables. It also has a lower environmental effect since it targets specific pest management features, reducing the chance of unintended consequences and environmental impact compared to broad-spectrum insecticides.

CRISPR is useful in protecting non-target creatures that play important roles in ecosystems, hence preserving ecological balance and biodiversity (Boete, 2018). It also makes it

Published: 21 April. 2024
ISSN: 2583-7850

easier to generate resistant crops through customised resistance, making crops more resistant to pest harm. However, there are several problems and factors to consider. Off-target effects must be handled using sophisticated CRISPR methods and extensive validation procedures. Ethical and regulatory issues are also being addressed, with legislative frameworks forming to ensure responsible use. CRISPR transforms pest control by providing a highly focused and effective tool for investigating and managing insect infestations.

Benefits of CRISPR

CRISPR technology has various advantages, including precise pest management, reduced environmental impact, pesticide resistance, agricultural resilience and new disease control. It enables the exact targeting of certain insect pests while causing minimal harm to non-target species, hence minimising ecological disturbances. CRISPR-based pest control can decrease environmental pollution and harm to non-target creatures by making genetic alterations that affect pests reproductive capacity or critical features (Karmakar *et al.,* 2022). It may also be used to generate crops with built-in insect resistance, eliminating the need for conventional pesticides. CRISPR can also be used to combat pesticide resistance by targeting and changing the genes involved, perhaps restoring the efficiency of present chemical control approaches. Furthermore, CRISPR can contribute to innovative disease control tactics by targeting disease vectors such as mosquitos for the Zika virus (Lull *et al.,* 2020).

Risks of CRISPR

Off-target consequences, ethical problems, regulatory hurdles, public perception and complicated ecological interactions are among the possible dangers of CRISPR, a genetic editing tool (Banerjee *et al.,* 2023). Because of the accuracy of CRISPR, off-target effects can occur, which can be avoided by thorough testing, validation and continual refinement. Ethical issues concerning ecological balance are raised by ethical considerations, particularly in the wild. Uncertainties and concerns regarding environmental and human health implications may result in regulatory barriers. Mitigation entails creating clear regulatory frameworks, conducting risk assessments and collaborating among scientists and regulatory authorities. Concerns about playing "nature's engineer" and unforeseen repercussions may limit public adoption of CRISPR in pest control.

Ethical considerations

The use of CRISPR technology for pest management in entomology poses ethical considerations, particularly concerning its possible environmental effect. The deliberate introduction of genetically engineered organisms can affect species dynamics, offering the possibility of unexpected effects (Bernaola and Holt, 2021). To detect possible effects on non-target species and ecosystems, thorough risk evaluations and ecological studies are required.

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Long-term ecological consequences may not be immediately evident, necessitating constant monitoring and adaptive management. The possibility of off-target effects, indirect impacts on non-genetically modified species and potential evolutionary repercussions raises ethical concerns regarding human-induced evolutionary alterations. Transparency, informed consent, the precautionary principle, regulatory supervision and international collaboration should be prioritised in ethical norms.

To minimise hazards, impacted communities and important stakeholders must provide informed permission and extensive risk assessments are required. Clear regulatory frameworks and rules are required for responsible CRISPR usage in entomology and coordination among scientists and regulatory agencies is required to design and implement ethical principles. Fostering international collaboration and information sharing is ethical because it encourages governments, researchers and organisations to work together to solve ethical problems and exchange best practices in the use of CRISPR (Ying *et al.,* 2023). CRISPR integration in pest management may be handled in a way that combines innovation with ethical and environmental sustainability.

Future Prospects

Future pest management might benefit greatly from CRISPR technology as research continues to improve accuracy, minimise off-target impacts and broaden the variety of alterations that can be made. It is anticipated that developments such as base editing and prime editing methods would further expand CRISPR's potential and offer more sophisticated control over genomic alterations (Sun *et al.,* 2017). As CRISPR develops, more focused, effective and adaptable entomology applications are anticipated, tackling pest-related issues in agriculture. The combination of CRISPR technology and other pest management measures, such as sterile insect techniques, biological control approaches and precision agriculture practices, is the way of the future for pest management. To fully use these integrated approaches and handle the complex nature of pest problems, geneticists, entomologists, ecologists and agronomists must work together (Singh *et al.,* 2022). With CRISPR's introduction into more extensive agricultural techniques, the field of pest management is about to undergo a revolutionary change.

Conclusion

The use of CRISPR in entomology signals a paradigm change in pest control, providing unparalleled accuracy and the promise of sustainable approaches. CRISPR's capacity to target specific genes in insect pests, delivering personalized treatments with minimal environmental effect, is revealed by recapitulating its role. However, as innovation advances, appropriate usage becomes increasingly important. Balancing CRISPR's transformational power with ethical concerns, rigorous monitoring and open communication guarantees that its implementation is

Published: 21 April. 2024
ISSN: 2583-7850

consistent with ecological sustainability and social values. Looking ahead, the consequences for entomology and agriculture are enormous. CRISPR has the potential to revolutionise pest control, improve crop resilience and contribute to global food security, highlighting the importance of ongoing research, international collaboration and ethical frameworks to guide its progress in transforming the agricultural environment.

References

Banerjee, S., Gupta, S., Raj, R., Kaushal, U., Kaur, G., and Gharde, S.K. (2023). CRISPR-Cas9 Technology: Mechanism and Its Application in The Field of Entomology. *Journal of Advanced Zoology*, 44(5), 179-193.

Bernaola, L., and Holt, J.R. (2021). Incorporating sustainable and technological approaches in pest management of invasive arthropod species. *Annals of the Entomological Society of America*, 114(6), 673-685.

Boete, C. (2018). Technoscience and biodiversity conservation. *Asian Bioethics Review*, 10(4), 245-259.

Dutta, P., Kumari, A., Mahanta, M., Upamanya, G. K., Heisnam, P., Borua, S., Kaman, P.K., Mishra, A.K., Mallik, M., Muthukrishnan, G., Sabarinathan, K.G., Puzari, K.R., and Vijayreddy, D. (2023). Nanotechnological approaches for management of soil-borne plant pathogens. *Frontiers in Plant Science*, 14, 1136233.

Karmakar, S., Das, P., Panda, D., Xie, K., Baig, M.J., and Molla, K.A. (2022). A detailed landscape of CRISPR-Cas-mediated plant disease and pest management. *Plant Science*, 323, 111376.

Lester, P.J., Bulgarella, M., Baty, J.W., Dearden, P.K., Guhlin, J., and Kean, J.M. (2020). The potential for a CRISPR gene drive to eradicate or suppress globally invasive social wasps. *Scientific Reports*, 10(1), 12398.

Lull, R.B., Akin, H., Hallman, W.K., Brossard, D., and Jamieson, K.H. (2020). Modeling risk perceptions, benefit perceptions, and approval of releasing genetically engineered mosquitoes as a response to Zika virus. *Environmental Communication*, 14(7), 933-953.

Medina, R.F. (2018). Gene drives and the management of agricultural pests. *Journal of responsible innovation*, 5(sup1), S255-S262.

Singh, S., Rahangdale, S., Pandita, S., Saxena, G., Upadhyay, S.K., Mishra, G., and Verma, P.C. (2022). CRISPR/Cas9 for insect pests management: A comprehensive review of advances and applications. *Agriculture*, 12(11), 1896.

Sun, D., Guo, Z., Liu, Y., and Zhang, Y. (2017). Progress and prospects of CRISPR/Cas systems in insects and other arthropods. *Frontiers in physiology*, 8, 608.

Suresh, J., Naganna, R., Nikhil, B.S.K., Reddy, S.S., and Reddy, CN. (2021). The CRISPR/CAS mediated genome editing: a novel insect pest management strategy. *Asian Journal of Microbiology, Biotechnology & Environmental Sciences*, 23(2), 205-212.

Vijayreddy, D. 2023. CRISPR-Cas9: A New tool in Plant Disease Management. *Vigyan Varta* 4(9): 251-253.

Ying, Y.A.N., Aumann, R.A., Haecker, I., and Schetelig, M.F. (2023). CRISPR-based genetic control strategies for insect pests. *Journal of Integrative Agriculture*, 22(3), 651-668.

Zhang, D., Zhang, Z., Unver, T., and Zhang, B. (2021). CRISPR/Cas: A powerful tool for gene function study and crop improvement. *Journal of Advanced Research*, 29, 207-221.

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Published: 21 April. 2024
ISSN: 2583-7850