CRISPR Genome Editing in Tropical Maize: Advancing Agricultural Sustainability at the University of Hawai'i

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UHM students attend CRISPR workshop hosted by the DuLab.

For millennia, selective breeding has served as the foundation for plant improvement, long before the discovery of DNA. This method relies on the natural emergence of genetic variants, with breeders selecting for desirable traits such as flavor, yield, and resilience. Selective breeding has significantly shaped modern agriculture, leading to crops with higher productivity and improved market value. The drawbacks of the traditional approach include its time-consuming process and reliance on spontaneous mutations.

Recent advancements in genetic engineering, particularly CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology, have revolutionized plant breeding by providing a precise and efficient tool for targeted genetic modifications. Unlike transgenic approaches, CRISPR enables site-specific gene edits without introducing foreign DNA. Solely using DNA from the organism itself reduces regulatory hurdles, allowing researchers to focus on enhancing specific plant traits such as: environmental resilience, nutrient content, and yield potential.

The Role of CRISPR in Modern Agriculture

UHM students attend CRISPR workshop hosted by the DuLab.

CRISPR has transformed agricultural biotechnology by allowing precise genome editing. This technique enables modifications that are crucial for addressing contemporary agricultural challenges, such as climate change and global food insecurity. For example, CRISPR has been used to develop crops with improved drought tolerance. Additionally, it has facilitated the enhancement of food quality, as demonstrated by the removal of bitterness from mustard greens without affecting their nutritional composition. Despite its numerous advantages, CRISPR technology presents ethical concerns and biological risks. Off-target gene effects and the potential for engineered traits to transfer to wild populations through hybridization must be addressed. Nonetheless, CRISPR remains a promising tool that could reshape agricultural systems by replacing slower and less precise traditional breeding methods.

CRISPR Research in Tropical Maize at the University of Hawai'i

At the University of Hawai'i at Mānoa's College of Tropical Agriculture and Human Resilience (CTAHR), a multidisciplinary research initiative is underway to harness the potential of CRISPR in tropical maize (*Zea mays*). The project is led by Dr. Michael Muszynski, assistant professor in the Department of Tropical Plant and Soil Sciences at

UH Mānoa. The team's work, in collaboration with Iowa State University, is supported by a $3.99 million grant from the National Science Foundation (NSF).

Dr. Michael Muszynski remarks on the Maize project at UH:

> Improved and practical crop breeding tools are required to meet the increasing demands of a growing global population and to overcome the sudden and variable stresses, made worse, by climate change. This project brings together researchers from the University of Hawaii at Manoa and Iowa State University to develop an efficient, robust genome engineering toolkit that can be used to speed the generation of resilient crops adapted to a changing environment. Reproductive barriers are a major bottleneck that limits the genetic diversity available for crop improvement. Tropical maize germplasm is a rich source of genetic diversity but its flowering behavior in temperate regions precludes its broad use for maize improvement. To access this diversity, our two institutions formed a collaboration that integrates our strengths in tropical plant biology and transformation (Hawaii) with maize transformation, genome engineering, and breeding (Iowa). Our goals are to establish a rapid and efficient genetic transformation platform and to develop improved genome editing tools to reprogram the flowering behavior of high-yielding tropical maize lines allowing their incorporation into any maize breeding program. Both Hawaii and Iowa will gain a valuable new capability in genetic transformation and genome engineering which will transform the types of crop research possible at both institutions. Expected impacts from this project will help address food security and economic weaknesses in Hawaii, by allowing for the development of new tropical crop

Maize nursery in Waimānalo

breeding industries. In Iowa, access to gene-edited temperate-adapted tropical germplasm will move maize improvement into the next era of genome-optimized breeding. Workforce capacity will be increased by engaging underrepresented students, particularly Native Hawaiians and Pacific Islanders, in diverse aspects of genome engineering research, by the exchange of undergraduates between partner institutions to prepare a globally competitive, multiculturally, and socially responsible workforce, and by creating opportunities for improved science communication skills through training sessions, workshops, and engagement with the community to communicate the value and

safety of these new tools.

Applications of CRISPR in Maize Improvement

In addition to modifying photoperiod sensitivity, the Muszynski Lab is exploring the use of CRISPR to enhance other vital traits in maize, including yield, nutrient content, and

stress tolerance. The precision of CRISPR enables researchers to directly target and modify genes responsible for these traits, potentially producing maize varieties that are more resilient to environmental stressors such as drought, heat, and nutrient-poor soils. This research addresses pressing global challenges by developing crops that can thrive in a range of growing conditions.

The application of CRISPR to tropical maize also has broader implications for sustainable agriculture. As maize is a staple crop in both tropical and temperate regions, improving its adaptability and productivity could substantially increase global food supply. By reducing the reliance on chemical inputs like fertilizers and pesticides, CRISPR-edited maize varieties could also contribute to more sustainable farming practices, helping to mitigate the environmental impacts of large-scale agriculture.

Future Directions and Implications for Global Food Security

The research being conducted at the University of Hawai'i represents a critical advancement in the application of CRISPR technology for crop improvement. The potential to adapt tropical maize for temperate regions, coupled with the ability to enhance key traits such as yield and stress tolerance, could significantly impact both agricultural productivity and food security.

As genome-editing technologies like CRISPR continue to evolve, their applications in agriculture will expand, providing novel solutions to some of the most pressing challenges facing global food systems. Careful consideration of ethical and ecological concerns will be continually necessary to ensure that these technologies are deployed responsibly.

The work of Muszynski and his team highlights the potential of CRISPR to drive innovation in plant breeding, offering new opportunities for improving crop resilience, increasing food production, and promoting sustainability. By unlocking the genetic potential of tropical maize, this research may pave the way for future breakthroughs that could reshape agricultural practices on a global scale.

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