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RESEARCH ARTICLE

TALENs and CRISPR/Cas Approaches for Rice Improvement through Genome Editing

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ABSTRACT

Rice, the staple food for half of the global population, is facing major production issues because of climate change, pest outbreaks, high usage of chemicals, and resource scarcity. Traditional breeding has improved its yield and resistance against stress, but slow pace and limited accuracy cannot keep up the demand of food. Genome technologies, such as TALENs, CRISPR/Cas systems have emerged as high paced high precision tools to accelerate rice productivity by enabling genome-specific edits to control the desired agronomic traits. Both systems usage induced method of double-strand DNA breaks at the very specific genomic sites, which are then restored by using specific. well grain quality. TALENs with tailoring DNA-binding domain are being used to improve rice's herbicide tolerance as weel grain quality. Advances in high-accuracy of CRISPR/Cas (Cas9 and Cas12) have enabled the targeted development of traits, such as high climate-stress resilience and superior grain quality of rice. Foreign DNA-free systems, such as TALENs and CRISPR/Cas producing non-gmos outcomes that align with sustainable future goals and green technology principles are more acceptable to regulators and consumers. In agriculture, these advancements lessen reliance on chemicals, better water management, and improve climate-resistance traits helping farmers with low-input high-output and locally adapted rice well grain quality. TALENs with tailoring DNA-binding domain are being used. With CRISPR and TALENS, the shift to environmentally responsible and sustainable agriculture is happening faster than ever.

Key words: CRISPR, rice, sustainability, talens

INTRODUCTION

Oryza sativa, known as rice, is the primary source food of more than half of the earth's citizens, but its production is constantly threatened by pest outbreaks, climate changes, overuse of agrochemicals, and resource shortages.[1] Conventional breeding has a very significant contribution in output improvement, but the very limited speed and low accuracy is not matching the required global food demand.[2] Gene editing tools, such as Transcription Activator-Like Effector Nucleases in short TALENs and CRISPR/Cas systems have arrived as precise and fast-paced tools to enhance rice production and enhance the quality of the rice.[3] Those tools are allowing accurate mutations of genomes which help to desirable traits.[4,5]

METHODS

TALENs-based Editing

It utilized customize DNA-binding domains fused with FOKL nuclease, these target specific gene of rice. This is used in precise gene knockouts and improvement in quality traits.[3]

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CRISPR/Cas-based Editing

CRISPR/Cas systems, importantly Cas9 and Cas12a, depend on guide RNAs that are directly complementary genomic sequences; those do require mutation in exact gene positions. By using this exact gene mutation happens, which improves both yield and quality.[6-8]

In summary, both those tools use no foreign DNAs, which helps with regulatory frameworks.

RESULTS

Precision Genome Editing

TALENs and CRISPR/Cas system successfully enabled targeted genome modification in rice by including site-specific double-strand DNA breaks, followed by precise knockouts, insertions, and sequence changes.[9]

Trait Improvement

Herbicide tolerance: Achieved using TALENs through DNA-binding domain tailoring.

Grain quality improvement: CRISPR/Cas9 and Cas12 improved upper grain traits.[10]

Climate-stress elasticity: Targeted edits increased tolerance to drought and other abiotic stresses.[5]

Sustainable Outcomes

Non-GMO approaches using those systems are aligned with environmentally sustainable practices.[6]

Reduced depends on chemical inputs and improved water-use efficiency.[11]

Locally adapted rice varieties with high yield and low input requirements were developed.

Overall Impact

The use of TALENs and CRISPR/Cas accelerates the shift toward environmentally responsible, sustainable, and climate-elastic rice production, supporting both farmer livelihood and global food security.[7]

DISCUSSION

Utilizing genome editing technologies, such as TALENs and CRISPR/Cas systems to improve rice is a paradigm shift from traditional breeding in agricultural biotechnology. Traditional breeding, with its long-generation times and imprecise trait targeting, limits the potential for genetic gain to develop new varieties of rice, as this is widely known.[8] On the other hand, TALENs and CRISPR/Cas technologies allow for targeted, precise, efficient, and rapid alteration of specific genomic loci, allowing for the trait embedding of desirable agronomic traits, such as yield, stress tolerance, and grain quality.[9]

TALENs have modifiable DNA-binding domains with demonstrated potential to enhance herbicide resistance and grain quality development. CRISPR/Cas systems offer a potential increase in versatility and may be more accurate than TALENs and to develop rice varieties that are resilient to climate stressors, pests, or resource constraints and putting more desirable agronomic traits into rice, it should be noted that there are both alternatives to develop molecularly edited rice varieties using an RNA interference strategy. Moreover, both are interesting because they both can be widely applied in DNA-free versions, where both systems work without DNA, giving non-GMO outcomes. I think this is less objectionable from a regulatory and consumer lens with biosafety and sustainability.[10]

Ultimately, these genome-changing technologies in rice can also function as stewards for environmental sustainability, for they can reduce reliance on chemical inputs, increase water usage efficiency, and climate adaptability will provide great contributions toward reducing greenhouse gas emissions.

CONCLUSION

Genome editing tools, such as TALENS and CRISPR/Cas system, are high-paced high-accuracy tools that are helping to improve output and quality of rice, which is a staple food for most of the countries. With TALENS CRISPR, the shift to environmentally responsible and sustainable agriculture is happening faster than ever.

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