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The Regulatory Role of Non-Coding RNAs in Enhancing Crop Stress Resilience under Climate Change

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Description

Non-coding RNAs (ncRNAs) have emerged as crucial regulators in plant biology, playing significant roles in gene expression, stress responses, and developmental processes [1]. Unlike messenger RNAs, ncRNAs do not code for proteins but instead modulate gene activity at transcriptional and post-transcriptional levels. In the context of climate change, which is intensifying environmental stressors such as drought, heat, and salinity, the regulatory functions of ncRNAs have become central to efforts aimed at enhancing crop stress resilience [2]. Through the precise regulation of stress-responsive genes, ncRNAs provide plants with dynamic and flexible defense mechanisms, making them valuable targets for modern crop improvement strategies [3].

Discussion

Climate change presents unprecedented challenges to global agriculture, with more frequent and severe abiotic stresses threatening crop productivity and food security. Plants have evolved complex molecular systems to perceive and respond to these stresses, and ncRNAs particularly microRNAs (miRNAs), small interfering RNAs (siRNAs), and long non-coding RNAs (lncRNAs) are integral to these regulatory networks [4]. These molecules act as fine-tuners of gene expression, either by silencing target genes, modulating mRNA stability, or interacting with chromatin to influence transcription. Their role in regulating stress-inducible genes enables plants to rapidly adapt to changing environmental conditions [5].

MicroRNAs, for example, are short RNA molecules that regulate gene expression by binding to complementary mRNA sequences, leading to mRNA degradation or translational repression. Several miRNAs have been identified that are specifically upregulated under stress conditions and target genes involved in stress signaling pathways, such as those controlling water use efficiency, ion transport, and antioxidant production [6]. Similarly, lncRNAs participate in stress regulation by acting as molecular scaffolds, decoys, or guides, influencing chromatin remodeling and gene accessibility. They can modulate the activity of transcription factors and other regulatory proteins that are essential in stress adaptation [7].

The potential of ncRNAs in enhancing crop stress tolerance is being actively explored through transcriptomic studies, functional genomics, and gene-editing technologies. RNA sequencing (RNA-seq) has allowed scientists to identify stress-responsive ncRNAs in various crop species, revealing their specific expression patterns and target genes under different stress conditions. For instance, in rice, miR393 regulates auxin signaling and improves drought tolerance, while in wheat and maize, certain lncRNAs have been linked to salinity and temperature stress responses. These findings underscore the potential of manipulating ncRNAs to improve crop resilience [8].

Biotechnological approaches, such as CRISPR/Cas-based genome editing and RNA interference (RNAi), are now being used to fine-tune ncRNA expression in crops. These techniques offer precise ways to enhance or suppress specific ncRNAs, enabling researchers to optimize plant responses to stress without altering the genome extensively. Furthermore, combining ncRNA manipulation with traditional breeding methods opens new avenues for developing climate-resilient varieties. However, challenges remain in translating this knowledge into field-ready solutions, including the complexity of ncRNA networks, off-target effects, and regulatory hurdles in genetic engineering [9].

As research advances, it becomes clear that a deeper understanding of ncRNA-mediated regulation is essential for future-proofing agriculture. Collaborative efforts among molecular biologists, agronomists, and breeders are necessary to harness the full potential of ncRNAs. Additionally, creating comprehensive databases and stress-responsive ncRNA libraries could accelerate their practical application in breeding programs [10].

Conclusion

In conclusion, non-coding RNAs represent a powerful and underutilized tool in the quest to enhance crop stress resilience under climate change. By modulating key gene networks involved in stress perception and response, ncRNAs offer a molecular toolkit for developing adaptable, high-performing crops. As climate-related stresses continue to jeopardize agricultural productivity, leveraging the regulatory potential of ncRNAs through advanced biotechnological and breeding strategies will be crucial. Continued research, innovation, and interdisciplinary collaboration will ensure that ncRNAs become central components of climate-smart agriculture and sustainable food systems.

References

1. Yusof HM (2019) Microbial Synthesis Of Zinc Oxide Nanoparticles And Their Potential Application As An Antimicrobial Agent And A Feed Supplement In Animal Industry: A Review. J Anim Sci Biotechnol 10:1-22.

2. Timilsina H (2021) Current Trends of Food Analysis, Safety, and Packaging. Int J Food Sci 23: 32-34.

3. Zhao Y (2021) Novel Strategies for Degradation Of Aflatoxins In Food And Feed: A Review. Int Food Res J 140: 32-34.

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4. Banaszak M (2021) Wheat Litter and Feed With Aluminosilicates For Improved Growth And Meat Quality In Broiler Chickens. Int Food Res 9:12-13.

5. Liang JF (2021) A Review of Detection of Antibiotic Residues in Food by Surface-Enhanced Raman Spectroscopy. Bioinorg Chem Appl. 8:27-32.

6. Zhang E (2021) Glycyrrhiza Polysaccharides Can Improve and Prolong the Response of Chickens to the Newcastle Disease Vaccine. Poult Sci 101:34-38.

7. Shang X (2021) Effects Of Zinc Glycinate On Growth Performance, Serum Biochemical Indexes, And Intestinal Morphology Of Yellow Feather Broilers. Biol Trace Elem Res 8:1-9.

8. Ramaswamy K (2021) Experimental Investigation on the Impacts of Annealing Temperatures On Titanium Dioxide Nanoparticles Structure, Size And Optical Properties Synthesized Through Sol-Gel Methods. Mater Today Proc 45:5752-5758.

9. Shah GA (2021) Toxicity of Nio Nanoparticles to Soil Nutrient Availability And Herbage N Uptake From Poultry Manure. Scien Repor 11:11540.

10. Banaszak M (2021) Aluminosilicates At Different Levels In Rye Litter And Feed Affect The Growth And Meat Quality Of Broiler Chickens. Vet Res Commun 46:37-47.