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Applications of Synthetic Biology In Agriculture

Dr.P.Jhansi Rani*[1], Mehraj[2] and Dr.G.Anusha[3]

[1]Assistant Professor, Dept.of GPBR,Agricultural College, Aswaraopet, PJTAU

[2]M.Sc(Ag student) at college of agriculture, Rajendranagar

[3]Teaching Associate, Dept.of GPBR,Agricultural College, Aswaraopet, PJTAU

* corresponding Author : jhansiranimadhira@gmail.com

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I. Plant synthetic biology as a tool to help eliminate hidden hunger

Introduction

The study "Plant Synthetic Biology as a Tool to Help Eliminate Hidden Hunger" focuses on addressing micronutrient deficiencies through plant biofortification. Hidden hunger refers to malnutrition resulting from insufficient vitamins and minerals despite adequate calorie intake. Using advanced techniques like genetic modification, CRISPR-based gene editing, and metabolic engineering, this approach enriches crops with vital nutrients such as vitamin A, vitamin D, iron, and omega-3 fatty acids, targeting areas with limited dietary diversity.

Objective

The aim is to enhance the nutritional content of plants by leveraging genetic modification, gene editing, and metabolic engineering. These techniques are employed to tackle malnutrition by making biofortified crops more accessible and nutritionally rich.

Materials

- Genetic Modification (GM): Adding transgenes to improve nutrient profiles.
- Gene Editing (GE): Using CRISPR/Cas9 for precise gene alterations.
- Metabolic Engineering (ME): Optimizing pathways to boost nutrient production.
- Synthetic Biology Tools: Employing promoters and transformation techniques for genetic control.
- Model Crops: Examples include rice (Golden Rice), wheat, tomato, soybean, and camelina.
- Nutrient Targets: Vitamins (A, C, D), minerals (iron, zinc), and macronutrients (proteins, lipids).

Methods

1. Genetic engineering to enhance nutrient profiles.
2. Modifying metabolic pathways for improved nutrient synthesis.
3. Designing promoters for controlled gene expression.

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4. Reducing antinutrients like phytates to enhance absorption.

5. Conducting field studies to evaluate the effectiveness of biofortified crops.

Procedure

- Identify target nutrients such as vitamin A, iron, and omega-3 fatty acids.
- Use genetic engineering tools (CRISPR/Cas9, transgenes) to improve nutrient biosynthesis.
- Optimize gene expression with synthetic promoters and codon adjustments.
- Suppress genes responsible for antinutrients to improve bioavailability.
- Test biofortified crops through DNA-free editing, expression studies, and field trials.

Key Results

- Successful biofortification includes crops like Golden Rice (Vitamin A), tomato (Vitamin D3), wheat and soybean (iron, zinc), and camelina (omega-3 fatty acids).
- Reduction of antinutrients enhances nutrient absorption in the human body.

Limitations

- Regulatory and consumer resistance to GM crops.
- Limited bioavailability of certain nutrients.
- High costs and complex metabolic pathways.

Conclusion

Synthetic biology provides effective tools for tackling hidden hunger through biofortification. Despite challenges, continued advancements in genetic engineering hold great promise for improving global nutrition and food security.

II. Synthetic biology : A powerful booster for future agriculture.

Introduction

The study "Synthetic Biology: A Powerful Booster for Future Agriculture" highlights the use of advanced synthetic biology techniques to address food security and environmental challenges. By improving crop yields, optimizing resource use, and reducing ecological harm, this approach showcases the transformative potential of synthetic biology.

Objective

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To explore how synthetic biology can enhance agricultural productivity and promote sustainable farming practices to combat the global food crisis and environmental degradation.

Materials Used

- Genetic materials for introducing desirable traits.
- Microorganisms to support soil health and crop growth.
- Tools for genetic manipulation and pathway optimization.

Methods Used

1. Optimizing metabolic pathways for greater crop productivity:

This is achieved by manipulating key pathways like photosynthesis, glycolysis, and nitrogen assimilation, often through gene overexpression or pathway engineering. Synthetic glycolate metabolism pathways can improve photosynthetic efficiency and yield in C3 crops.

Key Metabolic Pathways and Their Enhancement:

Photosynthesis: Enhancing the efficiency of photosynthesis, the process by which plants convert light energy into chemical energy, is crucial for improving crop yield. This can be done by manipulating enzymes involved in the process, like those in the Calvin cycle.

Glycolysis: Glycolysis is the breakdown of glucose to produce energy and building blocks for other metabolic processes. Optimizing this pathway can lead to increased energy availability for other processes,

Techniques for Optimizing Metabolic Pathways:

Gene Overexpression: Overexpressing genes encoding enzymes in key metabolic pathways can increase their activity and enhance the overall pathway flux.

Metabolic Pathway Engineering: This involves creating new or modified pathways to improve specific traits, such as increased yield or tolerance to stress,

2. Engineering crops with enhanced resilience, yield, and nutrition:

a. Enhanced Resilience:

Drought Tolerance: Crops like maize, soybean, and cotton have been engineered for drought tolerance, allowing them to produce higher yields even under water-scarce conditions. For example, drought-tolerant maize has shown a 20% yield increase in field trials in Kenya compared to conventional varieties.

Salt Tolerance: Rice has been engineered to resist salinity, enabling it to grow in areas with high salt concentrations in the soil.

Pest Resistance: Bt crops, which produce a natural insecticide, are resistant to specific insect

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pests, reducing reliance on chemical pesticides and improving yields.

Disease Resistance: Genetic engineering can also introduce genes that provide resistance to plant diseases, reducing crop losses and improving yields.

b. Increased Yield:

Improved Photosynthesis: Genetic engineering can enhance photosynthesis efficiency, leading to increased biomass production and yield.

Enhanced Nutrient Use Efficiency: Modifying genes related to nutrient uptake and utilization can help plants better absorb and utilize nutrients from the soil, resulting in higher yields.

Yield-Determining Genes: Identifying and manipulating genes that influence yield traits like grain number, size, and leaf growth can also lead to significant yield increases.

3. Using microorganisms for nitrogen fixation and soil enrichment: synthetic biology offers the potential to engineer microorganisms to enhance nitrogen fixation. This can involve modifying genes to increase nitrogenase activity, improving nitrogen transport, or expanding the range of plants with which nitrogen-fixing bacteria can form symbiotic relationships.

Procedure

1. Select crops based on agricultural needs.
2. Analyze metabolic pathways to identify areas for optimization.
3. Use synthetic biology to introduce beneficial traits into crops.
4. Apply nitrogen-fixing bacteria to enrich soil.
5. Test crops in controlled and field conditions to evaluate performance.

Results

- Increased crop yields and improved resource efficiency.
- Reduced dependence on water, fertilizers, and pesticides.
- Enhanced food security and environmental sustainability.

Conclusion

Synthetic biology offers transformative solutions to agricultural challenges. By improving productivity and sustainability, it contributes to a greener, more resilient global agricultural system.

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