ISSN: 2157-7439
Journal of Nanomedicine & Nanotechnology
OPEN ACCESS Freely available online
Case Report

Gene Delivery Systems: using Nanoparticles to Deliver DNA/RNA for Genetic Resistance in Plants

Taito Nakashima*

Department of Stem Cell Biology and Medicine, Graduate School of Medical Sciences, Kyushu University, Japan

ABSTRACT

Nanoparticle-mediated gene delivery offers a groundbreaking approach to enhancing plant resistance against diseases, addressing the limitations of traditional agricultural practices. This article explores the mechanisms and benefits of using nanoparticles as carriers for DNA and RNA, facilitating genetic modifications that confer resistance to various pathogens. Key synthesis components include metallic nanoparticles (e.g., gold, silver), polymeric nanoparticles (e.g., chitosan), and lipid-based nanoparticles (e.g., liposomes), each providing unique advantages in protecting and delivering genetic material. The process involves nanoparticle synthesis, genetic material loading, targeted delivery, and subsequent gene expression. Benefits include targeted delivery, protection of genetic material, reduced dosages, and enhanced uptake by plant cells. Despite challenges related to biosafety, delivery efficiency, regulatory approval, and cost-effectiveness, nanoparticle-mediated gene delivery holds significant promise for revolutionizing modern agriculture. This technology aims to develop resilient crop varieties, ensuring food security and sustainability amid global challenges.

Keywords: Nanoparticle-mediated gene delivery, Plant disease resistance, Genetic modification, DNA/RNA delivery, Agricultural biotechnology

INTRODUCTION

The increasing global demand for food, coupled with the challenges posed by plant diseases, necessitates the development of innovative and efficient agricultural practices. Traditional methods of plant disease management, including the use of chemical pesticides and breeding for resistance, have limitations such as environmental pollution, development of resistance in pathogens, and time-consuming processes [1,2]. In this context, nanobiotechnology, specifically the use of nanoparticles for gene delivery, presents a promising alternative for enhancing plant resistance to diseases.

The promise of nanoparticles in agriculture

Nanoparticles are materials with dimensions on the nanoscale, typically ranging from 1 to 100 nanometers. Due to their small size, large surface area, and unique physicochemical properties, nanoparticles can interact with biological systems in novel ways [3,4]. In agriculture, nanoparticles have been explored for a variety of applications, including targeted delivery of agrochemicals, soil health improvement, and plant disease management.

Mechanism of gene delivery using nanoparticles

The gene delivery process involves the introduction of foreign genetic material (DNA or RNA) into plant cells to induce genetic changes that confer resistance to diseases [5]. Nanoparticles serve as carriers for these genetic materials, facilitating their entry into plant cells and protecting them from degradation. The main steps in the nanoparticle-mediated gene delivery process are:

Synthesis of nanoparticles: Nanoparticles can be synthesized using various methods, including chemical, physical, and biological approaches. Commonly used nanoparticles for gene delivery include metallic nanoparticles (e.g., gold, silver), polymeric nanoparticles (e.g., chitosan), and lipid-based nanoparticles [6,7].

Loading genetic material: The genetic material, either DNA or RNA, is loaded onto or encapsulated within the nanoparticles. This can be achieved through electrostatic interactions, covalent bonding, or physical entrapment.

Targeting and Delivery: The nanoparticle-gene complex is applied to the plant, where it is taken up by plant cells through mechanisms such as endocytosis, direct penetration, or adhesion to cell walls [8]. Targeting can be enhanced by modifying the surface of nanoparticles with ligands that recognize specific plant

***Correspondence to**: Taito Nakashima, Department of Stem Cell Biology and Medicine, Graduate School of Medical Sciences, Kyushu University, Japan, E-mail: taitonakashima@gmail.com

Received: 01-May-2024, Manuscript No: jnmnt-24-25941, **Editor assigned:** 04- May -2024, Pre QC No: jnmnt-24-25941 (PQ), **Reviewed:** 18- May -2024, QC No: jnmnt-24-25941, **Revised:** 25- May -2024, Manuscript No: jnmnt-24-25941 (R), **Published:** 31- May -2024, DOI: 10.35248/2157-7439.24.15.726.

Citation: Nakashima T (2024) Gene Delivery Systems: using Nanoparticles to Deliver DNA/RNA for Genetic Resistance in Plants. J Nanomed Nanotech. 15: 726.

cell receptors.

Release and expression: Once inside the plant cell, the genetic material is released from the nanoparticles and incorporated into the plant's genome or expressed transiently. This leads to the production of proteins or RNA molecules that enhance the plant's resistance to pathogens [9,10].

Types of nanoparticles used in gene delivery

Metallic nanoparticles

Gold nanoparticles (AuNPs): Gold nanoparticles are widely used in gene delivery due to their biocompatibility, ease of synthesis, and ability to be functionalized with various biomolecules. AuNPs can efficiently deliver DNA or RNA into plant cells, facilitating gene expression and inducing resistance to diseases.

Silver nanoparticles (AgNPs): Silver nanoparticles possess antimicrobial properties in addition to their gene delivery capabilities. AgNPs can be used to deliver genetic material while simultaneously providing a direct defense against bacterial and fungal pathogens.

Polymeric nanoparticles

Chitosan nanoparticles: Chitosan, a natural polymer derived from chitin, is biodegradable and non-toxic. Chitosan nanoparticles can effectively bind to DNA or RNA and facilitate their delivery into plant cells. They also possess inherent antimicrobial properties, adding an extra layer of protection against pathogens.

Poly(lactic-co-glycolic acid) (PLGA)

Nanoparticles: PLGA nanoparticles are synthetic polymers known for their biodegradability and controlled release properties. They can encapsulate genetic material and provide sustained release, ensuring prolonged gene expression in plants.

Lipid-based nanoparticles

Liposomes: Liposomes are spherical vesicles composed of lipid bilayers. They can encapsulate DNA or RNA and fuse with plant cell membranes, delivering the genetic material directly into the cytoplasm. Liposomes can be modified with targeting ligands to enhance specificity.

Approaches to gene delivery

Transient gene expression: Transient gene expression involves the temporary introduction and expression of genetic material in plant cells. This approach is useful for short-term studies and applications where permanent genetic modification is not required. Nanoparticles can deliver DNA plasmids or RNA molecules (such as small interfering RNA, siRNA) to achieve transient expression of genes that confer resistance to specific pathogens.

Stable transformation: Stable transformation results in the permanent integration of foreign DNA into the plant's genome. This approach is essential for creating genetically modified crops with long-lasting resistance to diseases. Nanoparticles can deliver DNA constructs containing the desired genes along with selectable marker genes to facilitate the selection of transformed plants.

Benefits of nanoparticle-mediated gene delivery

Targeted delivery: Nanoparticles can be engineered to target specific plant tissues or cells, enhancing the efficiency and effectiveness of gene delivery.

Protection of genetic material: Nanoparticles protect DNA or RNA from degradation by nucleases, ensuring that the genetic material reaches its target intact.

Reduced dosage: The high surface area-to-volume ratio of nanoparticles allows for the use of lower dosages of genetic material, reducing potential toxicity and environmental impact.

Versatility: Nanoparticles can be used to deliver a wide range of genetic materials, including plasmid DNA, RNA interference molecules, and gene-editing components (CRISPR/Cas9).

Enhanced uptake: The small size of nanoparticles facilitates their uptake by plant cells, overcoming the barriers posed by the plant cell wall and membrane.

CONCLUSION

Nanoparticle-mediated gene delivery represents a revolutionary approach to enhancing plant resistance to diseases. By leveraging the unique properties of nanoparticles, researchers can achieve targeted, efficient, and safe delivery of genetic material, paving the way for the development of resilient crop varieties. As research progresses and challenges are addressed, this technology has the potential to transform modern agriculture, ensuring food security and sustainability in the face of growing global challenges.

REFERENCES

1. Cho J S, Hong Y J, Kang Y C. Design and Synthesis of Bubble-Nanorod-Structured Fe2O3–Carbon Nanofibers as Advanced Anode Material for Li-Ion Batteries. ACS Nano. 2015; 9: 4026.
2. Asoufi HM, Al-Antary T M, Awwad AM. Magnetite (Fe3O4) Nanoparticles Synthesis and Anti Green Peach Aphid Activity (Myzuspersicae Sulzer). Journal of Computational Biology. 2018; 6.
3. Esmaili N, Mohammadi P, Abbaszadeh M, Sheibani H. Green synthesis of silver nanoparticles using Eucalyptus comadulensis leaves extract and its immobilization on magnetic nanocomposite (GO Fe3O4/PAA/Ag) as a recoverable catalyst for degradation of organic dyes in water. Applied Organometallic Chemistry. 2020; 34(4): e5547.
4. Sandhya J, Kalaiselvam S. Biogenic synthesis of magnetic iron oxide nanoparticles using inedible borassus flabellifer seed coat: characterization, antimicrobial, antioxidant activity and in vitro cytotoxicity analysis. Materials Research Express. 2020; 7(1): 015045.
5. Zhang N, Li X, Wang Y, Zhu B, Yang J. Fabrication of magnetically recoverable Fe3O4/CdS/g-C3N4 photocatalysts for effective degradation of ciprofloxacin under visible light. Ceramics International. 2020.
6. Liu S, Yu B, Wang S, Shen Y, Cong H. Preparation, surface functionalization and application of Fe3O4 magnetic nanoparticles. Adv. Colloid Interface Sci. 2020; 102165.
7. Mirza S, Ahmad MS, Shah A, Ateeq M. Magnetic nanoparticles: drug delivery and bioimaging applications. 2020; 189-213.
8. Iravani S, Korbekandi H, Mirmohammadi SV, Zolfaghari B. Synthesis of silver nanoparticles: chemical, physical and biological methods. Int J Pharm Sci. 2014; 9(6): 385.
9. Sorbiun M, Shayegan Mehr E, Ramazani A, Mashhadi A. Biosynthesis of metallic nanoparticles using plant extracts and evaluation of their antibacterial properties. Nanochemistry Research. 2018; 3(1): 1-16.
10. Singh J, Dutta T, Kim KH, Rawat M, Samddar P, Kumar P. Green synthesis of metals and their oxide nanoparticles: applications for environmental remediation. Journal of nanobiotechnology. 2018; 16(1): 1-24.