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Mini Review

Multifunctional nanobiotics: Overcoming AMR and optimizing plant tissue culture

Alka Yadav[1], Parul Johri[2], Rajesh Kumar Tiwari [1], Mala Trivedi[1*]

[1]Amity Institute of Biotechnology, Amity University, Lucknow, Uttar Pradesh, India.
[2]Department of Biotechnology, Dr. Ambedkar Institute of Technology for Divyangjan, Kanpur, Uttar Pradesh, India.

Abstract

Antibiotics is a great invention that helped people to combat various bacterial infections. The infection used to turn into a deadly disease in the early times. This nano-sized material having antimicrobial power does a great deal in treating the lethal pathogens by inferring in the microbial system. Their effectiveness totally depends on their shape, size and other properties. The field of nanotechnology is multidisciplinary and has virtually endless applications in all fields from environment and agriculture to human health. The list of nanoparticles (NPs) is very large that are utilized in the above-mentioned sectors. These NPs, including Ag, TiO_2, Zn, and ZnO, have been primarily utilized for managing microbial pollutants in plant tissue culture. It is time to delve deeper into these rich reservoirs of nanotechnology since new-age materials like graphene, graphite, carbon nanotubes, quantum dots, and atomic clusters are being created and have proven bactericidal and fungicidal properties. The present review deals with applications of nanoparticles in diverse fields, viz., in human health as well as plant biotechnology. In the field of human health focus of nanobiotics is on countering antimicrobial resistance in a sustainable manner and in plant biotechnology role of nanobiotics is discussed in controlling contamination of *in-vitro* culture.

Keywords: Nanobiotics, Nanoparticles, AMR, Plant tissue culture, Micelles.

Introduction

In the coming future there are high chances of getting AMR in patients because the new strains of bacteria are becoming resistant to antibiotics. The invention, which was once considered a boon, is now being converted into a curse. This is because of misuse or often indiscriminate use of antibiotics that has led to the occurrence of these conditions.

The nanoparticles can have access to antimicrobial potentialities depending on their multivalent interaction and surface-to-surface volume ratio (Table 1). Oxides of metal of nano range and organic nanoparticles with antibacterial properties can safely treat any infection. These nanobiotics with various chemical formulations and intrinsic properties have diverse modes of action on the target (Chakraborty *et al*., 2022).

Their mode of action also depends upon external factors like pH, temperature, and aeration. These factors can influence their antibiotic activity. These qualities allow them to show their action in a different mechanism that helps to target the bacterial metabolic processes.

Bacterial plant diseases are difficult to manage due to the large populations of bacterial pathogens in sensitive plant hosts and the limited availability of bactericides. Antibiotics have been widely used as an alternative to control bacterial plant diseases since the 1950s, as they are effective in reducing bacterial population size and preventing disease outbreaks in the absence of long-lasting and powerful host disease resistance (Islam *et al.,* 2024).

Utilization of nanotechnology to tackle AMR

The nanobiotics have shown a great performance in the role of an antibiotic as compared to the traditional antibiotics we consume. It has been able to be possible by improving the pharmacokinetics of the drug where the distribution is only restricted to the target site, and it is

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*Corresponding author; Email: mtrivedi@lko.amity.edu
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Table 1: Nanoparticles in plant tissue culture – disclosed and undisclosed

S. No.	*Nanoparticle (NP)*	*Activity*
1.	Ag NPs, ZnO NPs, TiO_2 NPs	Disinfection
2.	Ag NPs, Cu/Co NPs, C nanotubes, ZnO NPs, Al_2O_3 NPs	Differentiation and morphogenesis
3.	Ag NPs, Au NPs	Somaclonal variation
4.	TiO_2 NPs, Ag NPs, Al_2O_3 NPs	Secondary metabolite production
5.	Dendrimers, Au NPs, Ag NPs	Genetic transformation

only achieved by reducing the volume also, by increasing the half-life in the serum. This is going to reduce the number of bacteria at lower drug dosages (Karanwal *et al.*, 2023).

The nanobiotics can be formed in two ways. In the first method, multiple numbers of the drug are encased in a single nanoparticle and another way is where one or more nanoparticles combine to form a hybrid nanoparticle (Crofts *et al.*, 2017). This increases the pharmacological effect of the drug, and it enhances the antibacterial power while checking the occurrence of resistance (Karanwal *et al.*, 2023).

Nanomaterials as antimicrobial substances

Use of organic nanoparticles

There are various substances used as organic nanoparticles. These are liposomes, polymeric micelle and solid/lipid nanoparticle. These particles can carry both hydrophilic and hydrophobic antibacterial agents (Muteeb, 2023)

Liposome and lipid nanoparticle

Liposomes and lipid nanoparticles are made of phospholipid bilayers. Also, they are spherical vesicles. Their spherical shape helps them to fuse with the membranes of bacteria and release the drug in it. Biofilm-mediated infections can be treated with this technique as its antimicrobial agents target the microbe causing infection *via* this method. Along with that, they have other features also, like target specificity, low toxicity and increasing efficiency of antibiotics (Nsairat *et al.*, 2022).

Solid/lipid nanoparticle

They are solid or colloidal lipid-based carriers. These are known to have very low toxicity and are quite stable. The drugs released by these particles are in limited amounts with high efficacy, whose working can be varied by the nature of the lipids, and temperature (Scioli *et al.*, 2020).

Polymeric micelles

These micelles are a buildup of block copolymers with colloidal structures. The polymers used to form polymeric micelles are polystyrene, polylactic acid, poly (propylene oxide), and poly (ethylene oxide). The micellar structure is hydrophobic from the core inside, while it is hydrophilic structure from the core outside (Perumal *et al.*, 2022).

Nanotechnological achievements in plant tissue culture

When it comes to plant tissue culture, microbial contamination is a significant issue. Even before the propagation mechanism has initially started, microbial contamination might end the entire process and reduce its effectiveness. The sources of contamination include the explants themselves and the laboratory setting. Before creating *in-vitro* cultures, the various explants obtained from field or greenhouse-grown plants are typically surface sterilized. However, this has frequently proven insufficient, leading to the damage of several experimental setups and the waste of work and time. Before starting an *in-vitro* culture, the explants' surfaces must be well cleaned because bacteria grow more quickly in tissue culture medium than the explants do and have the potential to negatively impact culture initiation. The disinfectant concentration and exposure period frequently impact the quality of the explants.

Furthermore, getting rid of indigenous bacteria is frequently quite difficult. Thus, the culture medium is supplemented with a number of antibiotics and $AgNO_3$ to either kill the bacteria or stop their growth. Antibiotics' phytotoxicity to cell, tissue, and organ cultures of different plant species has also been documented. Some disinfectants have even been shown to be phytotoxic, meaning that they have a significant negative impact on organogenesis rather than removing pollutants from explants (Hammer and Norskov, 1995). It has been demonstrated that metal and metal oxide nanoparticles are effective at killing a variety of bacteria. A wide range of NPs such as silver (Ag), aluminum oxide (Al_2O_3), CuO, iron oxide (Fe_3O_4), gold (Au), magnesium oxide (MgO), nickel (Ni), silicon (Si), SiO_2, titanium dioxide (TiO_2), and ZnO have been reported to possess antimicrobial activities against various microorganisms (Dijaz *et al.*, 2017; Ruttkay *et al.*, 2017). The addition of AgNPs to the media, apart from reducing the contamination rate, may influence the growth and development of explants (Perzymies, 2021). Ag NPs, for the first time, were used to control bacterial contamination in *Valeriana officinalis* (Abdi *et al.*, 2008). The extensive antimicrobial activity of nanosilver causes the inactivation of the bacterial transport chain *in-vitro* by binding to the sulfhydryl group of enzymes involved in the metabolic activities and also cohere to the microbial DNA to arrest the bacterial replication (Safavi *et al.*, 2011). Because of their distinct antibacterial mechanism, nanomaterials are able to overcome bacterial resistance and are being used in all biological fields (Qi *et al.*, 2020). Nanomaterials possess unique properties that make them less likely to cause bacterial resistance than traditional antibiotics. These properties include their small size and large specific surface area (Hammer and Norskov, 1995), their ability to enter cells and organelles (C), their ease of suspension in liquid (B), and their large optical and magnetic changes (Guo *et al.*, 2020). Therefore, nanomaterials have the potential to become antibacterial drugs. Metal and metal oxide nanoparticles have been extensively employed in antibacterial applications in recent years, yielding good results.

Influence of nanomaterials on somaclonal variation

Somaclonal variation refers to the alterations seen in organs and plantlets grown *in-vitro*. Chromosome number, chromosome structure, DNA sequencing, DNA methylation, mitotic crossing over, and activation of transposable elements are frequently linked to it. In plant tissue culture, somaclonal variation has both advantages and downsides. Plant size, flower color, leaf variegation, fruit ripening, synthesis of secondary metabolites, and resilience to biotic and abiotic stressors are only a few of the important traits that variations have. Numerous studies have shown that NPs, especially when used in higher quantities, are phytotoxic (Pathak *et al.*, 2023). Treatments with NP change the protein and DNA expression in plants, as well as the mitotic index and DNA integrity (Doo *et al.*, 2017). On MS medium containing CNPs, the ploidy level of *Linum usitatissimum* calli was considerably impacted. The addition of CNPs increased the proportion of tetraploid cells. In calli grown on media containing CNPs, DNA methylation levels were likewise greater. The effects of Au and AgNPs on somaclonal variation in *L. usitatissimum* were examined by Kokina *et al.*, 2017. Both calli and regenerated shoots grown on medium containing AuNPs as opposed to AgNPs had a higher incidence of somaclonal variation. According to Ewais *et al.*, 2015 the alteration of the protein and DNA profile in *Solanum nigrum* calli causes a change in callus morphology and anatomy when AgNPs are added to tissue culture medium. To ascertain the impacts of a variety of NPs on promoting somaclonal variation, more research is necessary.

Future prospects of nano-integrated plant tissue culture

The antibiotics developed saved the lives of many people and still are in high demand. But now in recent times, there are emerging cases of antimicrobial resistance where these antibiotics are a huge failure. This condition might have been increased in the COVID-19 pandemic due to the high usage of antibiotics which can later cause hindrance in treating bacterial infection due to the genesis of antibiotic-resistant strain microbes. In the past few years, nanobiotechnology has been placing its feet in the research field where, with the help of nanoparticles, various diseases can be treated due to its targeted drug of various diseases where it may play its role nanobiotics. In the current scennario nanoparticles playing a vital role in applied biotechnology in general and in plant tissue culture in particular. NPs have shown their beneficial functions from the initial phase through disinfection, differentiation of the callus, genetic change, somaclonal variation, and synthesis of secondary metabolites. After setting the stage, it is time to study and delve further into nano-resources and incorporate them into plant tissue culture because nanotechnology has more to offer. The application of nanotechnology is interdisciplinary and has virtually no bounds. A few NPs, such as Ag, TiO_2, Zn, and ZnO NPs, have so far been mostly exploited for controlling microbial contamination in plant tissue culture despite the fact that a wide variety of NPs have been shown to possess substantial antibacterial activity. It is time to go even further into these vast reservoirs of nanotechnology since cutting-edge substances like graphene, graphite, quantum dots, carbon nanotubes, polymer dendrimers, and atomic clusters are being produced, all of which have shown bactericidal and fungicidal properties.

Conclusion

Antimicrobial resistance, as well as plant nano-biotechnology, is undoubtedly becoming a well-known and promising topic with high potential for plant improvement, even with all of these unreported facts casting a shadowy background over the field. More focused research is needed to explain and streamline the process so that only the positive features can be utilized without being exposed to the negative impacts.

Author Contribution

AY- Writing the original draft, PJ: Curation of literature, RKT: Proofreading, MT Concept, Final draft, Proofreading.

Conflict of Interest

All the authors declare that there is no conflict of interest.

References

Abdi, G.H., Salehi, H., & Khosh-Khui, M. (2008). Nanosilver: A novel nanomaterial for removal of bacterial contaminants in valerian (*Valeriana officinalis* L.) tissue culture. *Acta Physiologiae Plantarum*, *30*, 709–714.

Chakraborty, N., Jha, D., Roy, I., Kumar, P., Gaurav, S. S., Marimuthu, K., ... & Gautam, H. K. (2022). Nanobiotics against antimicrobial resistance: harnessing the power of nanoscale materials and technologies, *Journal of Nanobiotechnology, 20*, 375. https://doi.org/10.1186/s12951-022-01573-9.

Crofts, T.S., Gasparrini, A.J., & Dantas, G. (2017). Next-generation approaches to understand and combat the antibiotic resistome, *Nature Reviews Microbiology, 15*, 422–434. doi: 10.1038/nrmicro.2017.28.

Dizaj, S.M., Mennati, A., Jafari, S., Khezri, K., & Adibkia, K. (2015). Antimicrobial activity of carbon-based nanoparticles. *Advanced Pharmaceutical Bulletin*, *5,* 19–23. doi: 10.5681/apb.2015.003.

Doo, H. K., Judy, G. & Iyyakkannu, S. (2017), Nanomaterials in plant tissue culture: the disclosed and undisclosed. *RSC Advances, 7*, 36492; 10.1039/c7ra07025j.

Ewais, A., Desouky, S. A., & Elshazly, E. H. (2015). Evaluation of Callus Responses of *Solanum nigrum* L. Exposed to Biologically Synthesized Silver Nanoparticles. *Nanoscience and Nanotechnology*, *5*(3), 45-56. DOI: 10.5923/j.nn.20150503.01.

Guo, Z., Chen, Y., Wang, Y., Jiang, H., & Wang, X. 2020. Advances and challenges in metallic nanomaterial synthesis and antibacterial applications. *Journal of Materials Chemistry* B, *22,* 4764–4777. https://doi.org/10.1039/D0TB00099J.

Hammer, B., & Norskov, J. K. 1995.Why gold is the noblest of all the metals, *Nature. 376*(6537), 238–240, https://doi.org/10.1038/376238a0, 2-s2.0-4143079428.

Islam, T., Haque, M.A., Barai, H.R., Istiaq, A., & Kim, J-J. (2024). Antibiotic Resistance in Plant Pathogenic Bacteria: Recent Data and Environmental Impact of Unchecked Use and the Potential of Biocontrol Agents as an Eco-Friendly Alternative. *Plants*, *13*(8), 1135. https://doi.org/10.3390/plants13081135.

Karnwal, A., Kumar, G., Pant, G., Hossain, K., Ahmad, A., & Alshammari, M. B. (2023). Perspectives on usage of functional nanomaterials in antimicrobial therapy for antibiotic-resistant bacterial infections. *ACS Omega*, *8*(15), 13492-13508. https://doi.org/10.1021/acsomega.3c00110

Kim, D. H., Gopal, J., & Sivanesan, I. (2017). Nanomaterials in plant tissue culture: the disclosed and undisclosed. *RSC Advances*, *7*, 36492-36505. DOI: 10.1039/C7RA07025J

Kokina, I., Mickeviča, I., Jermaļonoka, M., Bankovska, L., Gerbreders, V., Ogurcovs, A., & Jahundoviča, I. (2017). Case Study of Somaclonal Variation in Resistance Genes Mlo and Pme3 in Flaxseed (*Linum usitatissimum* L.) Induced by Nanoparticles. *International Journal of Genomics, 1676874*. doi: 10.1155/2017/1676874; PMID: 28326314; PMCID: PMC5343275.

Muteeb, G. (2023). Nanotechnology- A Light of Hope for Combating Antibiotic Resistance. *Microorganisms*, *11*(6), 1489. doi: 10.3390/microorganisms11061489. PMID: 37374990; PMCID: PMC10302692.

Nsairat, H., Khater, D., Sayed, U., Odeh, F., Al-Bawab, A., & Alshaer, W. (2022). Liposomes: structure, composition, types, and clinical applications. *Heliyon. 8*(5). e09394. doi: 10.1016/j.heliyon.2022.e09394. PMID: 35600452; PMCID: PMC9118483.

Pathak, A., Haq, S., Meena, N., Dwivedi, P., Kothari, S.L., & Kachhwaha, S. (2023). Multifaceted Role of Nanomaterials in Modulating *In-vitro* Seed Germination, Plant Morphogenesis, Metabolism and Genetic Engineering. *Plants (Basel), 12*(17), 3126. doi: 10.3390/plants12173126. PMID: 37687372; PMCID: PMC10490111.

Perumal, S., Atchudan, R., & Lee, W. (2022). A Review of Polymeric Micelles and Their Applications. *Polymers (Basel), 14*(12), 2510. doi: 10.3390/polym14122510. PMID: 35746086; PMCID: PMC9230755.

Ping, C., Kaifeng, Y., & Yiliang, H. (2023). The dynamics and transmission of antibiotic resistance associated with plant microbiomes. *Environment International, 176*, 107986. https://doi.org/10.1016/j.envint.2023.107986.

Qi, M., Li, W., Zheng, X.F., Li, X., Sun, Y., Wang, Y., Li, C. Y., & Wang, L. (2020). Cerium and its oxidant-based nanomaterials for antibacterial applications: a state-of-the-art review. *Frontiers in Materials*, *7*, 2296–8016.

Ruttkay-Nedecky, B., Krystofowa, O., Nejdl, L., & Adam, V. (2017). Nanoparticles based on essential metals and their phytotoxicity. *Journal of nanobiotechnology, 15*, 33.

Safavi, K., Esfahanizadeh, M., Mortazaeinezahad, D.H. & Dastjerd, H. (2011). The study of nanosilver (NS) antimicrobial activity and evaluation of using NS in tissue culture media. *International conference on life science and technology, 3*, 159-161.

Scioli Montoto, S., Muraca, G., & Ruiz, M. E. (2020). Solid lipid nanoparticles for drug delivery: pharmacological and biopharmaceutical aspects. *Frontiers in molecular biosciences*, *7,* 587997.

Vasyukova, I., Gusev, A., Zakharova, O., Baranchikov, P., & Yevtushenko, N. (2021, September). Silver nanoparticles for enhancing the efficiency of micropropagation of gray poplar (Populus × canescens Aiton. Sm.). IOP Conference Series: *Earth and Environmental Science*, International Forestry Forum "Forest ecosystems as global resource of the biosphere: calls, threats, solutions", Voronezh, Russian Federation, *875*. DOI 10.1088/1755-1315/875/1/012053.