AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 6, Issue 9
www.agriallis.com

Article Id
AL04378

# QUANTUM DOTS: NEXT SHIFT TO COMBAT PLANT DISEASE

[1]Madduri Umashankar and [2]Vineeth M*

Email
jeerlavineeth@gmail.com

[1]KSNUAHS, Shivamogga, Karnataka, India
[2]Department of Plant Pathology, UAS, GKVK, Bengaluru, India

The scientific community has witnessed a revolution in fields such as medicine and agriculture due to the remarkable capabilities of nanomaterials, which continue to astound scientists with every new discovery. Nanoscale semiconductor particles, or quantum dots (QDs), with a diameter of two to ten nanometers. These tiny particles have remarkable fluorescence properties, a crystalline structure, a high surface area-to-volume ratio, small size, and great stability. QDs are developed in three different architectural configurations: capping, shell, and core ligand combinations. QDs are very stable, water soluble, effective, sensitive, resilient, and biocompatible due to their surface chemistry, which may have advantages for crops and agriculture.

The worldwide crop productivity and economic sustainability of agriculture are being threatened by plant diseases. Typically, conventional chemical insecticides work well only when application rates are high, experience low delivery efficiency, encourage the emergence of pesticide resistance, and are particularly ineffectual against crop diseases like Verticillium that are economically significant. Fusarium wilt in bananas, cotton, and citrus huanglongbing (HLB). Thus, innovative disease management strategies need to be created to enhance agricultural productivity, sustainability, and resistance to biotic stress. In the last few years Numerous nanotechnology-enabled tactics have shown a great deal of promise to handle the expanding issues with global food security and the sustainability of agriculture.

## A Revolutionary Approach to Managing Diseases: Quantum Dots

The use of QDs, which are nanoscale semiconductor particles with sizes between 2 and 10 nm, has dramatically increased in the domains of imaging, medicine, and dialogue. The distinct qualities characteristic of these incredibly tiny particles is their high surface area to volume ratio, crystalline structure, tiny size, remarkable fluorescence characteristics, and high steadiness. Even yet, common compositions of QDs (indium, lead sulfide, telluride, cadmium sulfide, and selenium selenide) Indium arsenide and phosphide) shoDue to phytotoxicity, there is interest in using substitute, non-toxic components to create QDs with the potential for advantages to flora and farming (Ahmed et al., 2024).

## Nano-Enabled Agriculture for Plant Disease Management

An enhanced electrochemical enzyme linked immunosorbent test (ELISA) for the detection of banana bunchy top virus (BBTV) was created by Majumder et al. (2020). They have employed cadmium selenide (CdSe) quantum dots (QDs) as signal amplifiers for improved and precise detection. The main antibody used in the experiments was produced from the coat protein of BBTV. The assay's electrical impulses may be greatly amplified using CdSe QDs, making the procedure suitable for laboratory application. Electrical conduction revealed an impedance difference of around 100 Ω between the healthy and infected samples, and electrochemical ELISA was able to detect the virus in plant sap at a dilution of 1:25, as opposed to 1:10 for conventional ELISA.

## Quantum Dots Shifts Sunlight Spectrum to Speed Plant Resistance

Using a cleavable benzoic–imine covalent link, a novel pH-responsive pesticide delivery system based on kasugamycin-conjugated ZnO quantum dots (KAS-ZnO QDs) was created. In an acidic environment, the KAS and Zn2+ liberated from KAS-ZnO QDs may have a synergistic antibacterial effect. In comparison to KAS and NH2-ZnO QD treatments, the greenhouse experiment demonstrated that the application of KAS-ZnO QDs had a longer duration and stronger antibacterial action against Acidovorax citrulli, which causes bacterial fruit blotch disease in watermelon, and that it was non-toxic to plants. As a result, pH-responsive KAS-ZnO QDs may have a synergistic antibacterial impact and provide a fresh method for treating plant disease (Liang et al., 2019).

Microbial infections that cause plant diseases drastically lower agricultural production and exacerbate food insecurity. Lately, Qiu and colleagues.. demonstrated that polyethyleneimine Quantum dots MXene covered with (PEI) (QDs) increase cotton's tolerance. Protecting seedlings from Verticillium wilt disease by preserving oxidative equilibrium of the system. This discovery demonstrates how bespoke QDs can be applied to exacerbate crop disease opposition.

During pathogen colonization, the host undergoes metabolic reprogramming. Plant phenylpropanoid metabolites, whose metabolic flux is diverted from flavonoid and lignin synthesis, are necessary to accomplish regulatory roles in plant development and interactions with their surroundings11, 12. When GhLac1 is knocked down, the phenylpropanoid pathway's metabolic flux is redirected, which results in the buildup of jasmonic acid (JA) and secondary metabolites that give V. dahliae and cotton bollworm13 resistance. One of the main characteristics of plant defenses is the burst of reactive oxygen species (ROS) caused by pathogens14. When avirulent pathogens infect an area, the quick build-up of ROS causes local cell necrosis, which stops the pathogens from growing.

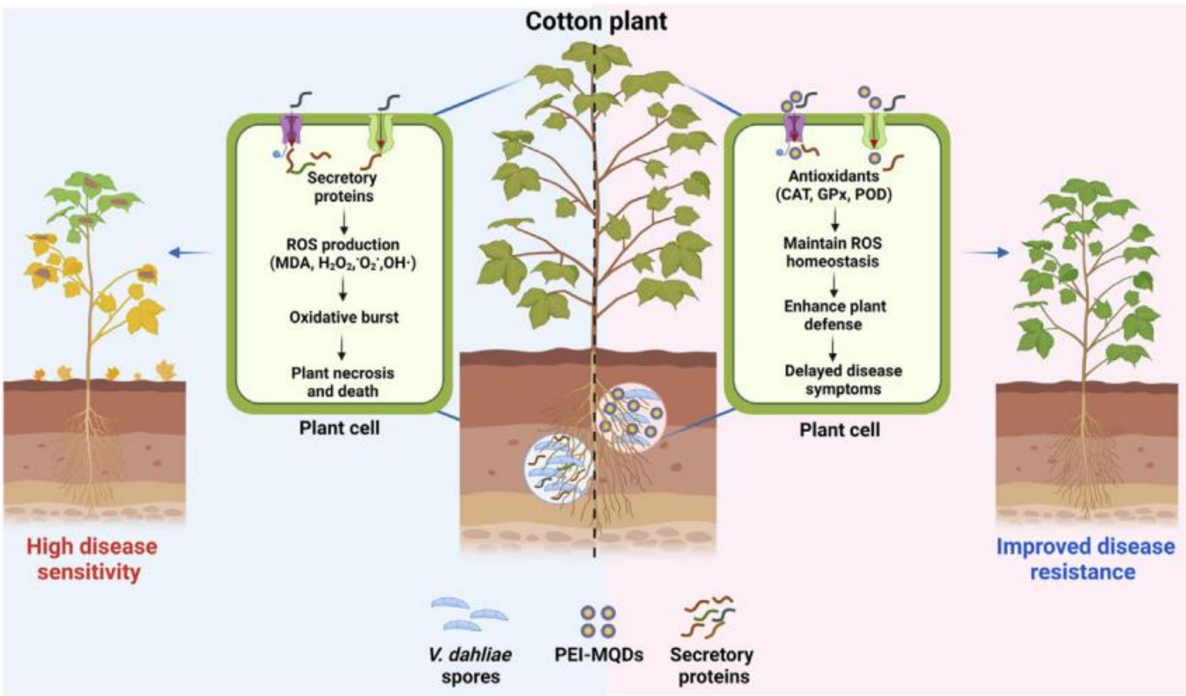


**Fig. 1:** Proposed mechanism for the protective effects of polyethyleneimine (PEI)-coated MXene quantum dots (PEI-MQDs) in cotton plants infected by Verticillium dahlia

When cotton plants are afflicted with the fungal disease V. dahliae, excess reactive oxygen species (ROS) are produced. PEI-MQDs have the ability to effectively scavenge these ROS. PEI-MQDs efficiently penetrate plant cells and selectively target several ROS, such as

superoxide anion (•) O2 hydroxyl radical (OH•), malondialdehyde (MDA), hydrogen peroxide (H2O2), and ), and aid in the breakdown of them. Furthermore, PEI-MQDs are essential for improving the operations of important antioxidant enzymes found in plants, including glutathione peroxidase (GPx), peroxidase (POD), and catalase (CAT) cells. The enhancement of antioxidant defenses by enzymes plays a role in the general upkeep of reactive oxygen species plant equilibrium infected by virus. Following PEI-MQD treatment, there was a notable decrease in leaf damage is seen, indicating that cotton plants are more resilient to V. dahliae infection.

## Quantum Dots and Their Interaction with Biological Systems

Kostov et al. (2022) observed the establishment of three more fungal plant infections, namely Botrytis cinerea, Alternaria alternata, and Fusarium oxysporum, as well as the oomycete plant pathogen Phytophthora infestans, in the presence of Carbon QDs (CQDs). Furthermore, research was done on CQDs' capacity to enhance the gene silencing that exogenous dsRNA causes in P. infestans. At relatively low concentrations, the results demonstrated the considerable inhibitory activity of CQDs against P. infestans. Additionally, they discovered that P. infestans was not rendered gene-silencing when exposed to naked dsRNA in vitro. In growing sporangia, the combination of CQDs and dsRNA resulted in a notable decrease in the transcript levels of the target gene GPB1, hence increasing RNA interference efficiency.

## Conclusion

Plant pathology's use of Quantum Dots offers a promising new avenue for the fight against plant diseases by providing instruments that improve the precision, efficacy, and efficiency of disease control techniques. QDs have the potential to significantly impact sustainable agriculture by boosting gene silencing mechanisms in pathogens, enabling more accurate pesticide administration, and improving the sensitivity of diagnostic assays. The establishment of unique QDs in the future will improve efficiency even more and provide researchers with new avenues to explore potentials in various agricultural applications.

## References

Ahmed, T., Noman, M., White, J.C., Ma, C., Wang, Q. And Li, B., 2024, Quantum dots: next shift to combat plant diseases. Trends Plant Sci., 29(7): 724-730.

Kostov, K., Lilova, B. And Smagghe, G., 2022, Inhibitory activity of carbon quantum dots against Phytophthora infestans and fungal plant pathogens and their effect on dsRNA-induced gene silencing. Biotechnol. Biotechnol. Equip., 36(1): 949-959.

Liang, Y., Duan, Y., Fan, C., Dong, H., Yang, J., Tang, J., Tang, G., Wang, W., Jiang, N. And Cao, Y., 2019, Preparation of kasugamycin conjugation based on ZnO quantum dots for improving its effective utilization. J. Chem. Eng., 30(1): 671-679.

Majumder, S., Bhattacharya, B., Singh, P.K., Johari, S., Singh, B. And Rahman, R., 2020, Impedimetric detection of banana bunchy top virus using CdSe quantum dots for signal amplification. SN Appl. Sci., 30(2): 71-77.