

Growth Effects of Fluorescent, Biopolymer-Coated Gold Nanoparticles on Hydroponically Grown Basil

Madison Johnson and David J. Kirby*

Department of Chemistry, The College of Wooster, 943 College Mall, Wooster, OH

Abstract

Gold nanoparticles (AuNPs) were coated with biopolymers such as polystyrene sulfonate (PSS) and chitosan, and fluorescent labels were attached to study plant uptake and enable tracking within plant tissues. Particle characterization using dynamic light scattering (DLS), zeta potential analysis, fluorescence microscopy, and TEM showed that several modification methods successfully increased particle size. However, fluorescence tracking was only successful with one synthetic strategy. When basil plants grown hydroponically were exposed to 1 mg of fluorescent AuNPs, confocal imaging detected nanoparticle-associated fluorescence in certain tissues; however, measurements of leaf dry mass and area revealed no significant growth differences compared to controls ($p > 0.05$), suggesting that under the experimental conditions, nanoparticle exposure did not affect plant growth.

Background

Why Nanoparticles (NPs) in Agriculture

- Rising food demand is increasing interest in technologies that improve crop productivity.
- NPs may improve nutrient delivery, stress tolerance, and overall efficiency.
- Understanding NP behavior in edible plants is essential for assessing safety and practical use.



Image adapted from reference 1

Why Gold Nanoparticles (AuNPs)

- Chemically stable, low toxicity, and highly tunable for biological applications.²
- Unique nanoscale properties (optical, chemical, surface area-to-volume ratio) enable tracking and functionalization.

Importance of Surface Modifications

- Coatings prevent aggregation, improve stability, and enhance interactions with biological systems.
- Fluorescent tagging enables visualization of NP uptake and movement in plant tissues.
- Surface chemistry directly affects NP transport, reactivity, and potential toxicity.

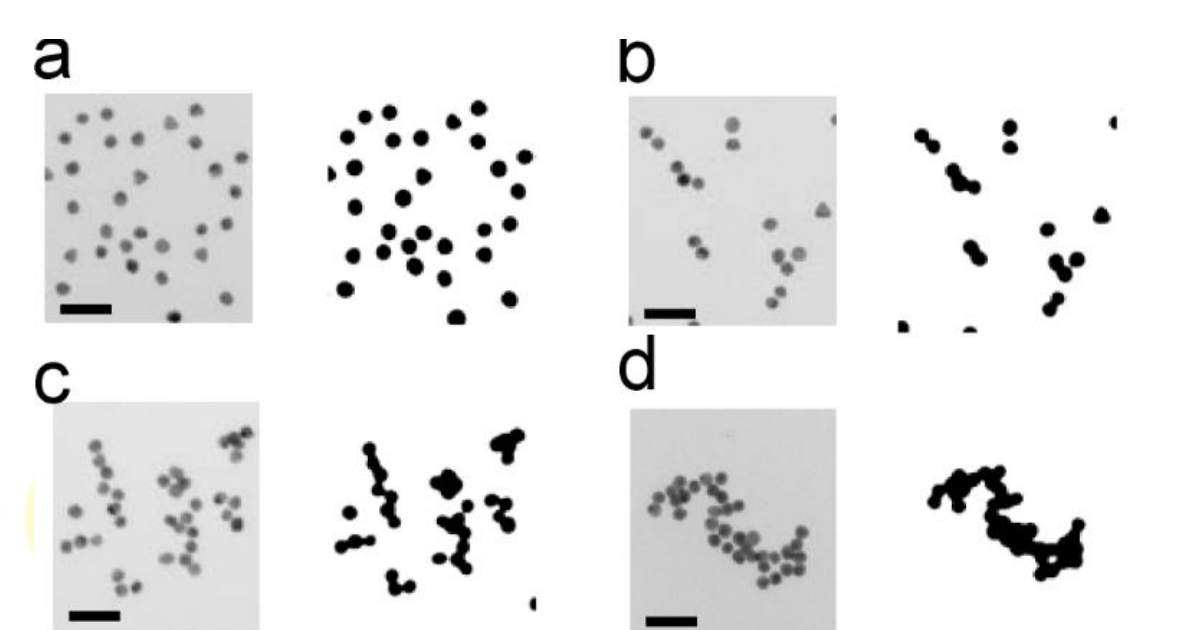


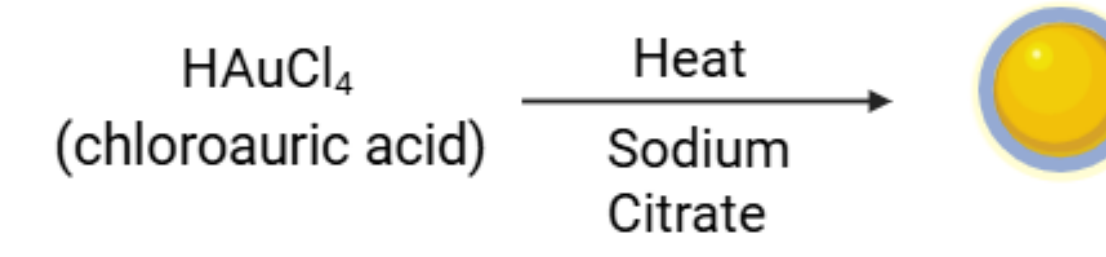
Image on the right adapted from reference 3, showcasing AuNP aggregation over time

Knowledge Gaps Driving This Study

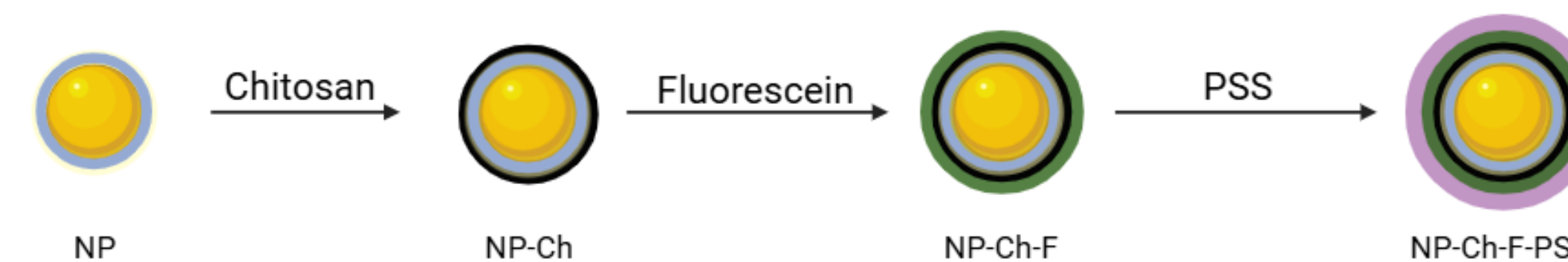
- AuNPs show species-dependent effects on growth
- Limited data exist for surface-modified, fluorescent AuNPs in edible crops.
- Key uncertainties remain about NP uptake pathways, localization within tissues, and potential impacts on plant growth.

Particle Synthesis and Characterization

Citrate-stabilized AuNPs:

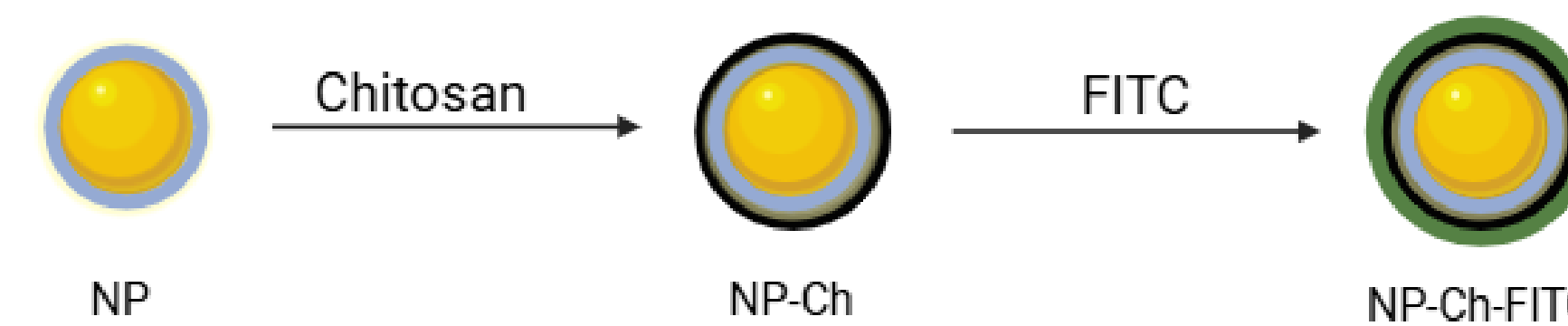


Method A: Using a Layer-by-Layer System



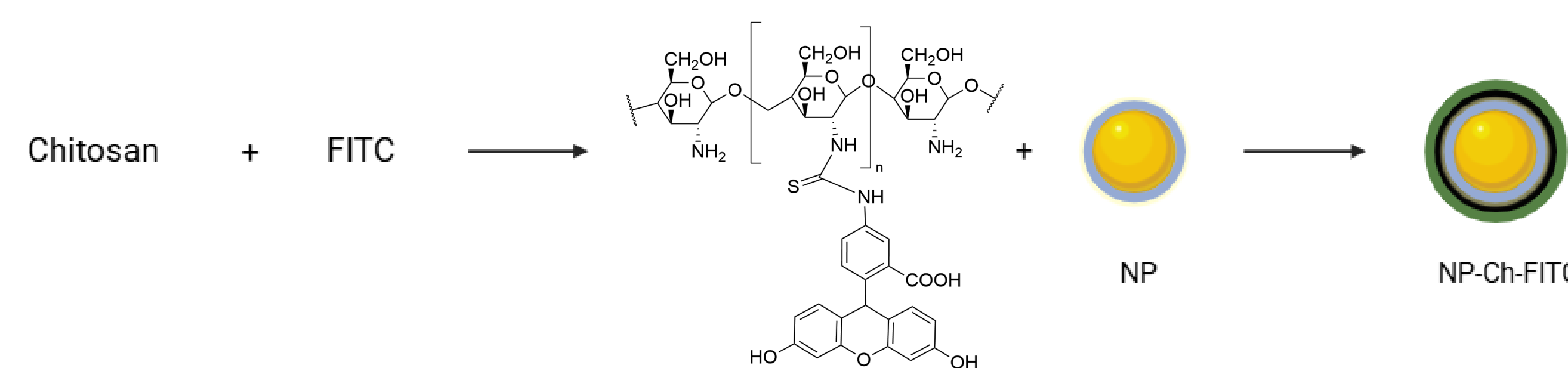
Solution	Effective Diameter (nm)	Zeta Potential(mV)
AuNP	104.54	-58
NP-Ch	278.02	-35
NP-Ch-F	345.12	-35
NP-Ch-F-PSS	368.37	-30

Method B: Fluorescein Isothiocyanate (FITC) Covalently Bound to NP-Ch



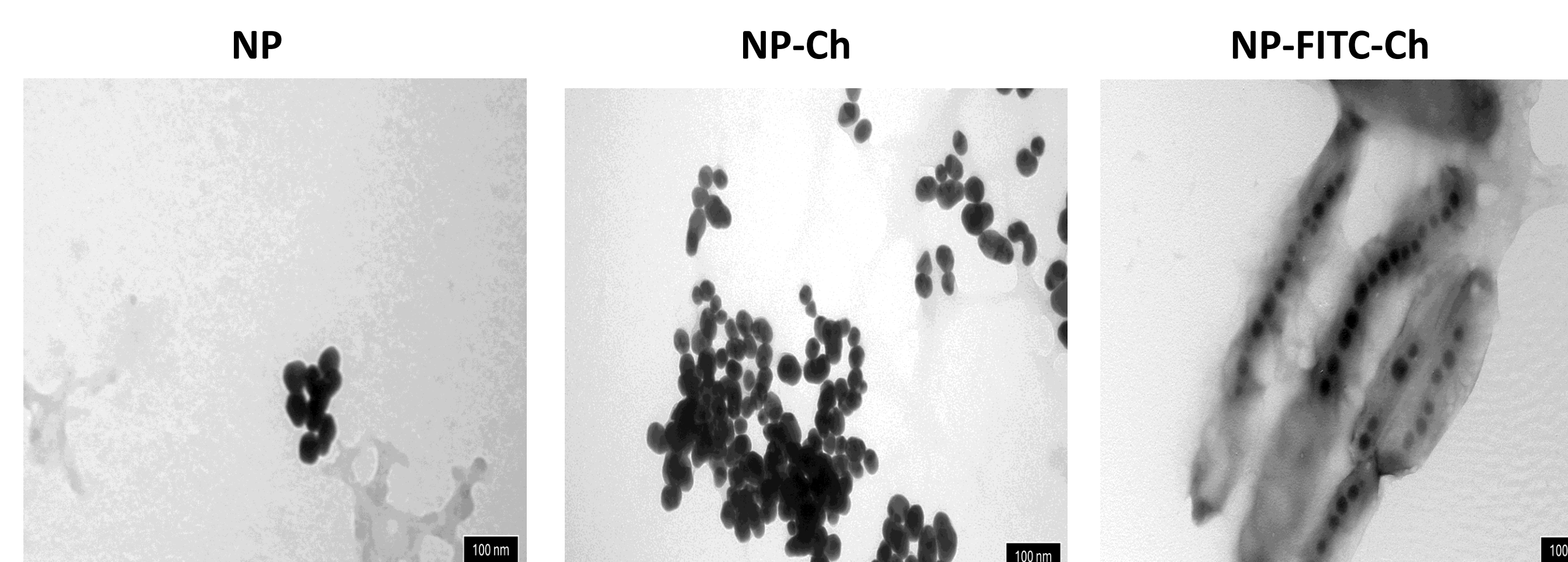
Solution	Effective Diameter (nm)
AuNP	104.54
NP-Ch	246.35
NP-Ch-FITC	259.74

Method C: FITC and Chitosan Binding



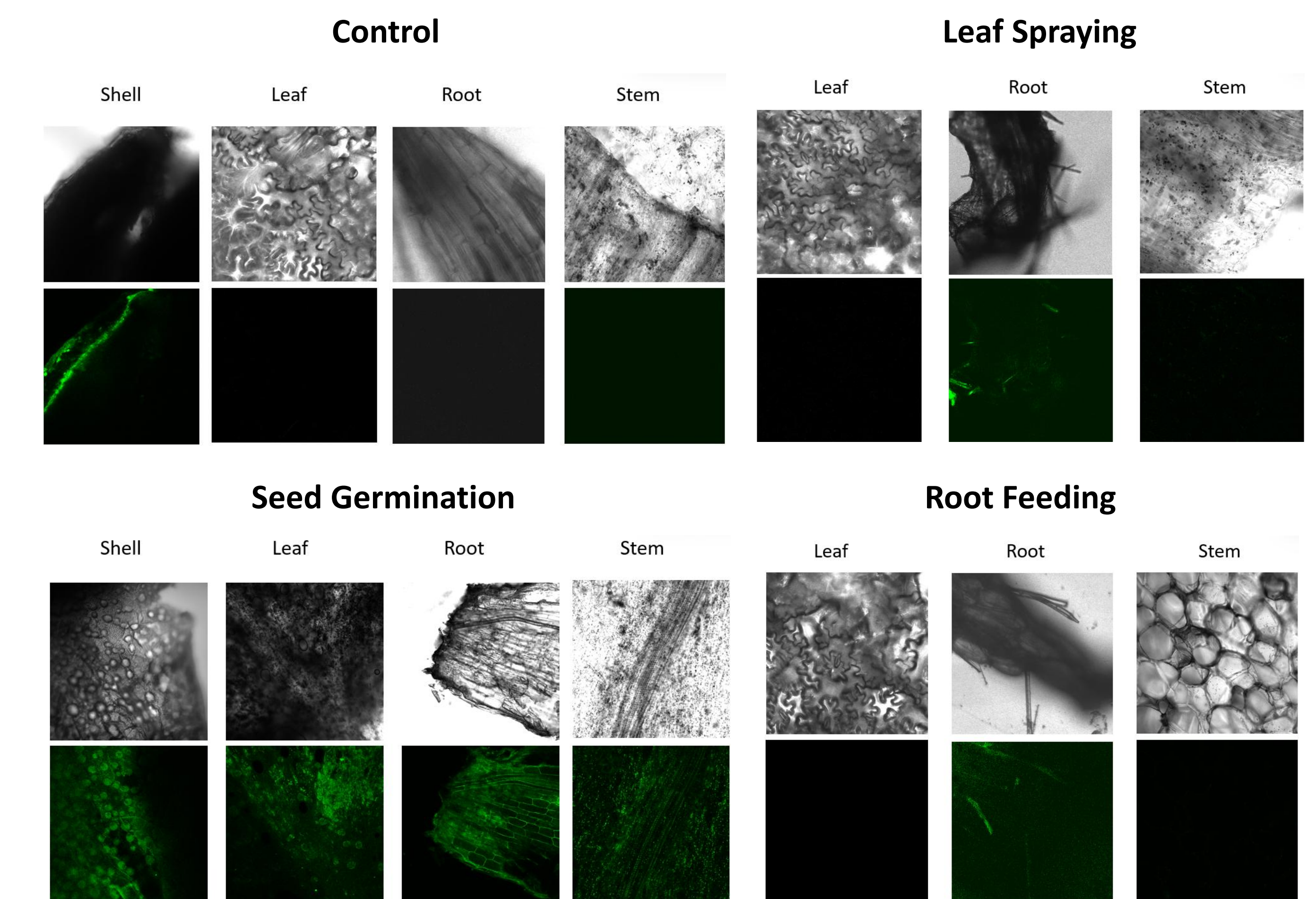
Solution	Effective Diameter (nm)	TEM Size Data (nm)
AuNP	104.54	25.556 ± 5.6
NP-FITC-Ch	171.22	28.737 ± 5.3 (shell thickness)

TEM Imaging



Plant Application

- Application methods included root feeding, foliar spray, and seed priming.
- 1 mg of AuNPs applied to the systems
- Hydroponics provides controlled, uniform exposure and easier access to roots.



- Leaf area analysis and dry mass were insignificant between control and experimental plants
- Images taken using confocal microscopy

Conclusions

This study successfully produced stable, fluorescent biopolymer-coated gold nanoparticles, and although fluorescence was detectable in basil tissues, no significant changes in growth were observed. Future work should verify true nanoparticle uptake with more detailed imaging and explore longer exposures, varied concentrations, and early developmental stages to better understand nanoparticle behavior in plants. Additionally, further investigation into the structure of NP-Ch-FITC from method C to determine if this is a repeatable and stable structure.

Acknowledgments

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References

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- 2) Gautam, K.; Singh, H.; Sinha, A. K. Nanotechnology in Plant Nanobionics: Mechanisms, Applications, and Future Perspectives. *Advanced Biology n/a* (n/a), 2400589.
- 3) Albanese, A.; Chan, W. C. W. Effect of Gold Nanoparticle Aggregation on Cell Uptake and Toxicity. *ACS Nano* **2011**, *5* (7), 5478–5489.
- 4) Gautam, K.; Singh, H.; Sinha, A. K. Nanotechnology in Plant Nanobionics: Mechanisms, Applications, and Future Perspectives. *Adv. Biol. n/a* (n/a), 2400589.