

Zinc and Iron Nanoparticles Using Cow Manure and Their Application as Nano Nutrients

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Abstract: This work investigates the environmentally sustainable production techniques for Zinc (Zn) and Iron (Fe) nanoparticles with a focus on their use as Nano-fertilizers to improve plant growth. Using nanotechnology, which is defined as the manipulation of matter at the nanoscale (1-100 nanometers), will achieve maximum efficiency in terms of nutrient delivery through agricultural practices. The study produced Zn and Fe nanoparticles using cow manure extract in the green synthesis method. Characterization was confirmed through UV-Vis and photoluminescence spectroscopy to achieve nanoparticles. The Nano-fertilizers were applied to chilly and tomato plants, leading to significant increases in chlorophyll content and other parameters like flowers, fruits, leaves, fruit size, clearly showing the potential to improve plant growth and yield.

Keywords: Nano fertilizers, Zinc nanoparticles, Iron nanoparticles, Cow manure extract, Green synthesis

I. Introduction

Nanotechnology has been among the most revolutionizing technologies of the twenty-first century, with nanoscale materials, ranging from 1 to 100 nm in diameter, finding a variety of applications (Belay et al., 2023; Patel et al., 2021; Rajput et al., 2020). It is an emerging interdisciplinary area of research that can potentially solve global problems in a cost-effective and environmentally friendly manner. Nanoparticles (NPs) differ from bulk materials in size and surface area, owing to which they possess unique properties, such as electrical conductivity, magnetism, chemical reactivity, visual effects, and physical strength (Sajid, 2022; Saleh, 2020). Two main strategies are used for producing NPs: The “top-down” technique involves breaking down larger materials into their constituent atoms and molecules to create NPs. The “bottom-up” approach starts with the most significant components and works upwards (Zulfiqar and Ashraf, 2021). NPs can be one-, two-, or three-dimensional, with spherical, tubular, or irregular shapes (Zulfiqar and Ashraf, 2021). Although traditional agrochemicals are widely used in agriculture to protect and increase crop productivity, they are associated with drawbacks, such as low bioavailability, susceptibility to photolysis, and environmental pollution (Perna Mehta et al., 2024; An et al., 2022; Odewale et al., 2023). In contrast, Nano-agrochemicals leverage the nanotechnology to overcome these issues. Owing to their peculiar size and characteristics, they provide improved administration of active ingredients and their greater bioavailability, while exerting a lesser adverse impact on the environment (Shelar et al., 2023; Singh et al., 2023b).

The key applications of nanotechnology include advanced Nano formulations of agrochemicals, which improve the application of pesticides and fertilizers, leading to better crop improvement and yield (Bhaskar et al., 2023; Tiwari, 2022). Nano sensors play a crucial role in crop protection by aiding the identification of plant diseases and detection of agrochemical residues, allowing for timely interventions and improved crop health (Kamari et al., 2023; Sheikh et al., 2024). Nano-formulated materials can inhibit plant pathogens locally and in various parts of the plant by translocating through all the conductive vessels of plants, thereby, reducing the incidence of diseases (Ali et al., 2020a). Organic nanomaterials, particularly those based on polymers or biopolymers, are potential carriers for active organic ingredients (Patra et al., 2018). The functionalization of their surfaces and encapsulation of specific active ingredients are challenging but essential for controlled release. Nano formulations are crucial for treating plant diseases by ensuring slow delivery of active ingredients, protecting them from degradation, and improving their solubility to enhance their inhibitory effect against phytopathogens (Avila-Quezada et al., 2022a; Ristaino et al., 2021; Su et al., 2019).

Green synthesized nanoparticles for Nano fertilizers are clearly not a harmful method as synthesis of metal salt are done using plant extract (Nongbet et al., 2022). Nanoparticles play an important role as nutrients carriers by delivering necessary nutrients to exact target sites in living system. Nanoparticles with particle size lower than the diameters of the cell wall pores (5–20 nm) of plants, can enter directly in the plant cell through the sieve-like cell wall (Fleischer et al., 1999). Nano fertilizers are considered as they greatly improve crops growth and yield, reduce nutrients loss, increase fertilizers efficiency and reduction in negative environmental impacts when compared to conventional fertilizers (Bhanushali et al. 2017, Singh et al., 2017). They have higher reactivity with other compounds due to their smaller size and large surface area (Daniel et al., 2004). In this paper we study green synthesis, characterization, and application of NPs in a agriculture. We apply this on chilly and potato, also studied quality of the plant as well as yield.

II. Research Methodology

Material

Cow dung, distilled water, Zinc acetate, ferric nitrate, etc.

III. Method

Preparation Of Cow Dunk Extract

Weigh approximately 23 g of fresh, dried, and powdered cow manure (Collected from Kalyan, East) and transfer it into a clean 500 cm³ beaker. Add 100 cm³ of distilled water and allow the mixture to soak for 2–3 hours at room temperature and boil for 45 minutes. Allow the mixture to cool to room temperature, then centrifuge it to obtain a clear solution of cow dunk.

Synthesis Of Metal Nanoparticles

Prepare a 1 M solution of zinc acetate by dissolving the appropriate amount of zinc acetate in distilled water to make up a final volume of 100 ml. Mix 100 mL of the prepared cow manure extract with 100 mL of the 1 M Zinc acetate solution in a clean reaction vessel. Stir the mixture thoroughly and allow it to stand undisturbed at room temperature for 12 hours to facilitate the reaction. A similar procedure was followed for the preparation of Iron Nanoparticles.

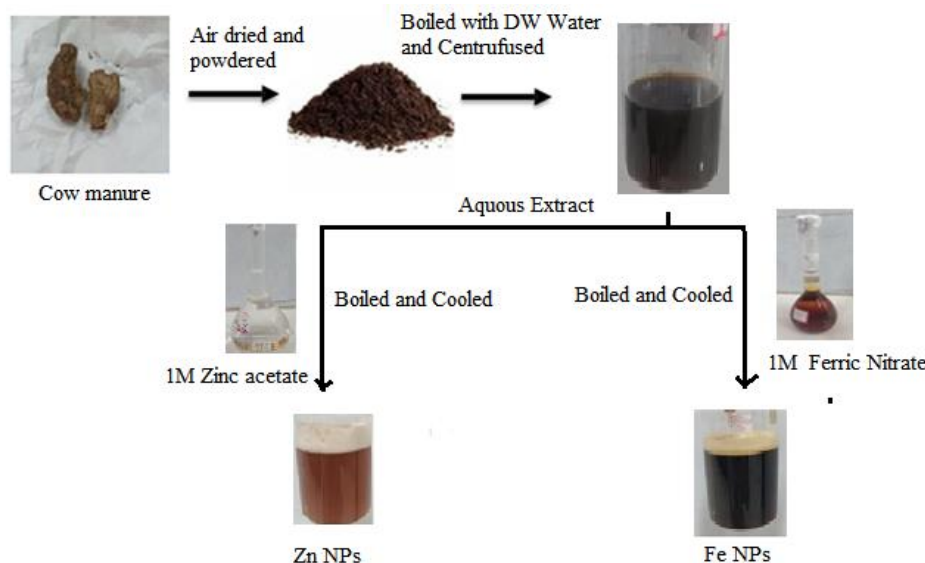


Figure 1: Scheme of preparation of Zn and Fe nanoparticles using cow manure extract

Characterisation

As synthesised Metal NPs were characterised by using UV-Visible Spectroscopy, Photoluminescence Spectroscopy and X-Ray Diffraction.

Application of Metal Nanoparticles to Tomato and Chili Plants

Tomato (*Solanum lycopersicum*) and Chilly (*Capsicum annuum*) seedlings were procured from Pathare Nursery, Kalyan. A total of 20 tomato and 20 chilly plants were cultivated in the Biodiversity Garden of B.K. Birla College, Kalyan MS, India. Among these, 10 plants of each crop were treated with a foliar spray of nanoparticle-based Nano fertilizer, while the remaining 10 plants of each served as untreated controls. Both treated and control groups were maintained under identical environmental and agronomic conditions throughout the experimental period. Plant growth and development were monitored over one month, with a focus on morphological characteristics and overall vigor. At the end of the one-month period, key growth and yield parameters were recorded and analyzed for both treated and control groups

IV. Results And Discussion

UV spectroscopy

UV-Vis spectroscopy measured the absorption spectra of Zinc NPs and Iron NPs nanoparticles from 200–450 nm, revealing a significant peak at 330 nm. This wavelength aligns with the known absorption range of 300–350 nm for these nanoparticles, confirming their successful synthesis of transition metal nanoparticles.

Photoluminescence Spectroscopy

Photoluminescence (PL) spectra of Zn and Fe nanoparticles synthesized using cow manure extract. The spectra are represented in figure 2 (a) excitation spectrum of Zn NPs, (b) excitation spectrum of Fe NPs, (c) emission spectrum of Zn NPs, and (d) emission spectrum of Fe NPs. Zn nanoparticles exhibit a sharp excitation and emission peak, indicating strong luminescence behavior, while Fe nanoparticles show a broader excitation and emission profile, suggesting multiple energy transitions and relatively lower PL intensity.

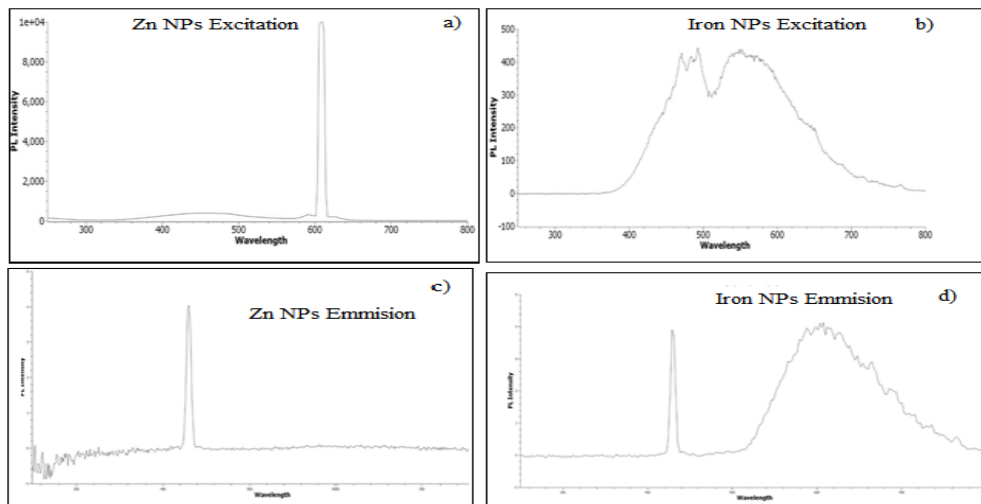


Figure 2 Photoluminescence spectra of nanoparticles synthesized using cow manure extract: (a) excitation and (b) emission spectra of ZnO NPs; (c) excitation and (d) emission spectra of Fe₂O₃ NPs.

Likewise, the Fe-based nanoparticles show a characteristic emission profile and excitation peak, validating their formation. Overall, the PL analysis confirms the successful synthesis of both ZnO and Fe-based nanoparticles, aligning their optical properties with expected characteristics.

X-Ray diffraction Analysis

To carry out the X-Ray diffraction analysis, the Zn and Fe NPs solution was dried and annealed at 400 °C in an oven. Figure 3 (a) XRD pattern for Zn-based nanoparticles which has sharp, intense, well-resolved diffraction peaks, meaning it is crystalline. Since the diffraction peaks were sharp, diffraction peaks should be observed for good long-range order. The various peaks indexed in the XRD pattern as ZnO Zincite, syn, strongly suggest that zinc oxide nanoparticles were successfully synthesized. The distinct major diffraction peaks were observed at 2θ values of approximately 31.7°, 34.4°, 36.2°, 47.5°, 56.6°, 62.8°, 66.3°, 67.9° and 69.0°. The indexed value of 2θ is likely referring to the quartzite structure of ZnO, as shown in two of the JCPDS Card Numbers (01-089-1397, 01-089-7102 and 00-036-1451) provided in the legend. The measured peak heights of Zn-based particles with these 2θ values will likely give a high degree of crystallinity since the indexed peaks were sharp and fall nicely when comparing one pattern with other similar XRD patterns, suggesting good long-range order. Since the widths of these peaks are relatively narrow, this also suggests the crystallites must be well-defined.

Overall, this pattern using the same indexed values of the standard ZnO patterns shown in the legend provides more confidence for the crystalline zinc oxide was synthesized successfully. The absence of significant impurity peaks suggest a high purity of synthesized ZnO nanoparticles.

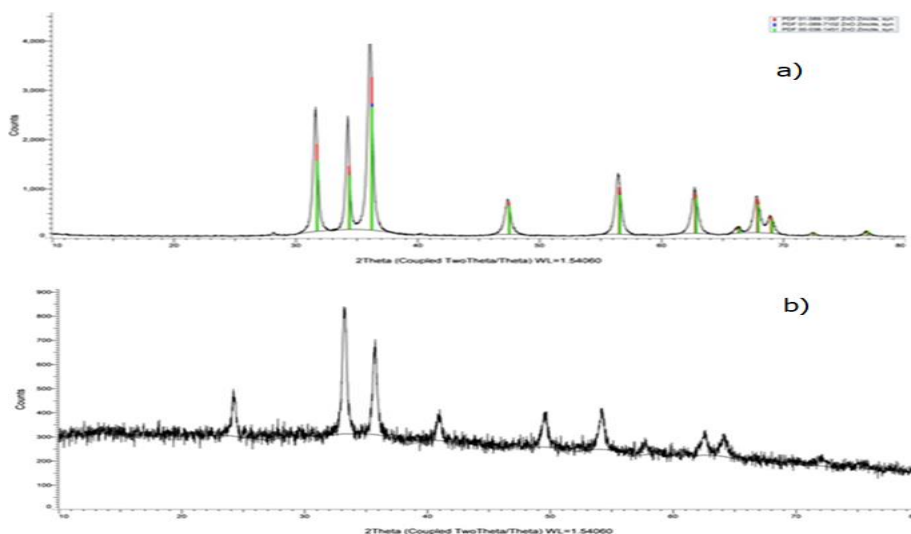


Figure 3 X-Ray analysis a) ZnO and b) Fe₂O₃ Nanoparticles obtained using Cow manure

The XRD pattern of Ferric oxide nanoparticles is shown in Figure 3 (b). The XRD pattern for the Ferric oxide nanoparticles has several distinct peaks with a relatively high background noise, largely at the low 2-theta values and shows sharp aspect ratio, indicating a crystalline material.

The largest diffraction peaks appear around 2θ of 35.5° , 37.1° , 43.1° , 50.1° , 57.0° , and 62.5° . To make definitive identifications of the phases, typically, these peak positions would be matched to standard crystallography databases. Based on the general look and a few common Fe oxide phases, the peaks match well to crystalline phase iron oxides like magnetite (Fe_3O_4), because they have similar crystal structures (inverse spinel), which would yield overlapping reflections. The peaks are broad with respect to what is known for a perfectly crystalline bulk material, which indicates that the particles were indeed in a nanometer range. The background noise could have originated from instrument influences or amorphous content in the sample as suggested in the image.

Application of Metal Nanoparticles to Tomato and Chili Plants

Approximately 20 ml of Zn and Fe nanoparticles (e.g., 25–100 ppm) is dispersed in distilled water and the solution is sonicated for 20–30 minutes for uniform dispersion and to avoid agglomeration. Healthy tomato (*Solanum lycopersicum*) and chili (*Capsicum annuum*) seedlings of uniform size (15–20 days old) are selected. Plants are maintained under controlled greenhouse conditions before treatment. The nanoparticles are applied in two ways: Spray and Soil Drenching. Control plants are treated with water only. Experimental plants receive different concentrations of Zn and Fe NPs (e.g., 25 ppm, 50 ppm, 75 ppm, 100 ppm). Treatments are applied at regular intervals (every 7–10 days).

Plants are monitored for growth parameters such as plant height, number of leaves, leaf area, and overall biomass. Flowering and fruiting responses are recorded. Chlorophyll content and yield are analyzed after treatment. The growth of plants before and after treatment is shown in Figure 4.

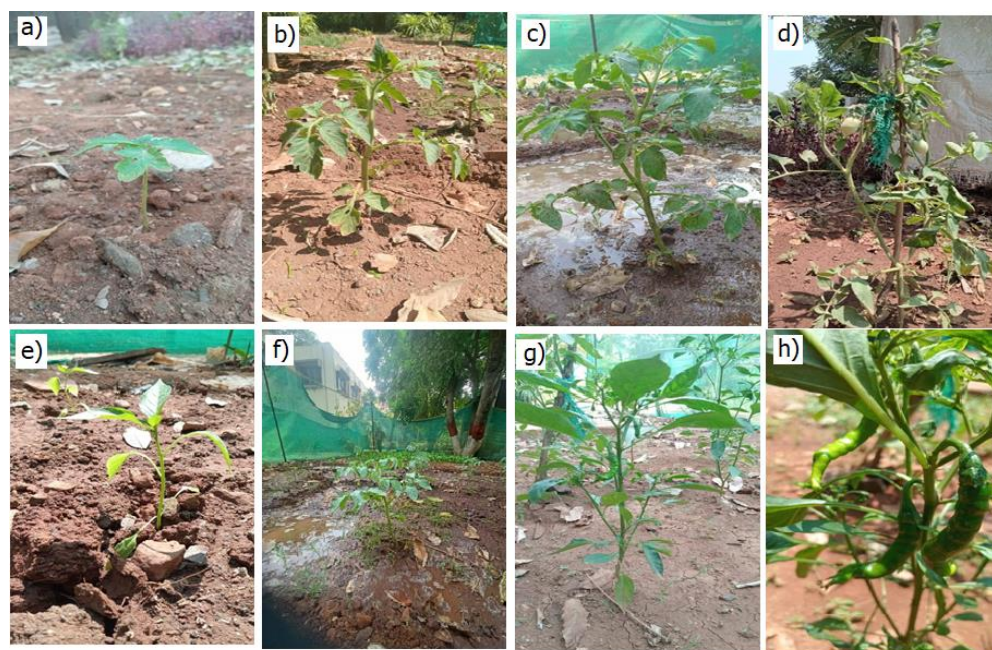


Figure 4 Images of an application of Metal Nanoparticles to a Tomato plant after transplanting a) 10 days old plant b) 20 days old plant c) 60 days old plant and Chilly plant after transplanting a) 10 days old plant b) 20 days old plant c) 60 days old plant

Table 1 presents a comparative analysis of growth and yield parameters in chili (*Capsicum annuum*) and tomato (*Solanum lycopersicum*) per plants under control and nanoparticle-treated conditions. The results clearly demonstrate the positive influence of metal nanoparticles on plant growth, physiology, and productivity.

The recent study is controlled by a relatively limited experimentation period, sample size, and a for specific plant types, this provides valuable preliminary insights into the potential of nano-fertilizers. These results serve as an important foundation for understanding their role in plant growth and soil health. The results highlight the need for extended trials across different crops, soil types, and environmental conditions to establish long-term effects and scalability. Thus, this study contributes meaningfully to the growing body of research and opens avenues for broader, more comprehensive investigations in the future. The study shows the impact of nanoparticles on plants and soil, and the results indicate no significant effects. This may be attributed to the method of green synthesis, the very low concentration of nanoparticles applied, and the fact that cow manure itself is an organic fertilizer. In addition to enriching the soil, cow manure likely acted as a reducing and stabilizing agent during the large-scale formation of metal nanoparticles.

Table 1 Comparative analysis of control and nanoparticle-treated chili and tomato plants using metal nanoparticles

Sr. No.	Parameters (Per plant)	Chilly		Tomato	
		Control	With NPs	Control	With NPs
1.	No. of Leaves (20 Days)	60	80	20	30
2.	Flowers (30 Days)	3	4	5	5
3.	Chlorophyll content (mg)	2.5	3.01	3.6	4.1
4.	Fruits (60 Days)	4	5	6	7
5.	Plant height (inches)	19	25	26	35
6.	Fruit size	7 cm in length	8 cm in length	7 cm in diameter	9 cm in diameter

V. Conclusion

This project successfully demonstrated the green production of Zn and Fe nanoparticles utilizing cow manure extract, and the use of the nanoparticles as Nano-fertilizers sufficiently increased the chlorophyll content of chilly and tomato in each selected plant. The nanoparticles exhibited unique UV-Vis absorbance, photoluminescence and XRD, which confirmed their synthesis. The Nano-fertilizer demonstrated a significant increase in chlorophyll in the treated plants, which promotes photosynthetic efficacy, and increases crop yield. This work highlights the potential of green-synthesized Nano-fertilizers for enhancing sustainable agriculture. The study shows the impact of nanoparticles on plants and soil, and the results indicate no significant effects.

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