



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 1479-1482
Received: 19-04-2026
Accepted: 23-05-2026

SU Gousia

Ph.D. Research Scholar,
Department of Agronomy, S.V.
Agricultural college, Acharya N. G.
Ranga Agricultural University,
Tirupati, Andhra Pradesh, India

V Chandrika

Associate Director of Research,
Regional Agricultural Research
Station, Acharya N. G. Ranga
Agricultural University, Tirupati,
Andhra Pradesh, India

R Naseeruddin

Scientist (Agronomy), RARS,
Nandyal, Acharya N. G. Ranga
Agricultural University, Guntur,
Andhra Pradesh, India

TNVKV Prasad

Principal Scientist (Soil Science),
Institute of Frontier Technology,
Regional Agricultural Research
Station, Acharya N. G. Ranga
Agricultural University, Tirupati,
Andhra Pradesh, India

P Latha

Professor and Head, Department
of Crop physiology, S.V.
Agricultural college, Acharya N. G.
Ranga Agricultural University,
Tirupati, Andhra Pradesh, India

Corresponding Author:

SU Gousia

Ph.D. Research Scholar,
Department of Agronomy, S.V.
Agricultural college, Acharya N. G.
Ranga Agricultural University,
Tirupati, Andhra Pradesh, India

Synthesis of zinc oxide nanoparticles and their optical and morphological characterization

SU Gousia, V Chandrika, R Naseeruddin, TNVKV Prasad and P Latha

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7s.6134>

Abstract

Zinc (Zn) is a vital micronutrient that regulates a wide range of physiological and biochemical processes in plants, including enzyme activation, protein biosynthesis, chlorophyll formation, membrane stabilization and reproductive development. Despite its importance, the effectiveness of conventional zinc fertilizers is frequently constrained by rapid fixation, precipitation and limited mobility in soil, resulting in poor nutrient availability and low fertilizer-use efficiency. Nanotechnology provides a promising avenue for improving zinc delivery through the development of nanoscale formulations which possesses high surface-area-to-volume ratios, enhanced reactivity and potential biological efficacy. In the present study, zinc oxide nanoparticles were synthesized through the oxalate decomposition chemical method and systematically characterized to establish their optical, morphological and functional attributes. Fourier transform infrared spectroscopic (FT-IR) analysis of the synthesized ZnO nanoparticles confirmed the nature of materials as oxide and the different functional groups that are associated with ZnO nanoparticles. UV-Visible spectroscopy revealed a distinct absorption maximum at approximately 370 nm, confirming the formation of nanoscale ZnO. Micrographs of scanning electron microscopy (SEM) showed that the particles were predominantly irregular to nearly spherical, with dimensions below 100 nm. The synthesized material therefore represents a promising candidate for development as a zinc-based nano-fertilizer aimed at improving zinc availability, nutrient-use efficiency and crop nutritional performance under agricultural conditions.

Keywords: Nanotechnology, zinc oxide, SEM, FT-IR, agriculture

Introduction

Nanotechnology has emerged as a transformative technology for developing advanced nutrient delivery systems in agriculture (Ayenew *et al.*, 2025) [2]. Materials engineered at the nanoscale possess unique physicochemical properties, including a high surface-area-to-volume ratio, enhanced surface reactivity and improved interaction with biological systems, making them suitable for efficient nutrient delivery. Among various nanomaterials, metal oxide nanoparticles have attracted considerable attention because of their stability, ease of synthesis and potential to improve fertilizer-use efficiency while minimizing nutrient losses to the environment (Ravishankar *et al.*, 2025) [5].

Zinc is an essential plant micronutrient involved in numerous physiological, biochemical and metabolic processes. It acts as a structural and catalytic component of several enzymes and proteins and plays a crucial role in chlorophyll synthesis, photosynthetic activity, auxin metabolism, membrane integrity and reproductive growth. However, the agronomic efficiency of conventional zinc fertilizers is often reduced by adsorption, precipitation and fixation reactions in soil, particularly under alkaline conditions, resulting in poor zinc availability to crops. (Abegunde *et al.*, 2026) [1]. The development of nanoscale zinc fertilizers has therefore gained considerable interest as an alternative approach to enhance zinc availability and nutrient-use efficiency.

Zinc oxide nanoparticles (ZnO NPs) have emerged as one of the most promising nanomaterials for agricultural applications because of their high chemical stability, biocompatibility, large specific surface area and controlled nutrient-release behaviour. The physicochemical characteristics of ZnO nanoparticles are largely governed by the synthesis route and reaction conditions, including precursor concentration, pH, temperature, calcination conditions and reaction time (Swain *et al.*, 2025; Rani *et al.*, 2025) [6, 4]. Consequently, optimization of the

synthesis process together with detailed characterization is essential for obtaining nanoparticles with desirable properties suitable for agricultural applications.

Reliable characterization is indispensable for confirming nanoparticle formation and understanding their properties. Ultraviolet–Visible (UV–Vis) spectroscopy is widely employed to verify the composition formation through their characteristic optical absorption behaviour. Fourier Transform Infrared (FT-IR) spectroscopy provides information on the functional groups and chemical bonding associated with the synthesized nanoparticles and confirms the removal of precursor compounds after synthesis. Scanning Electron Microscopy (SEM) enables direct visualization of particle morphology, surface texture and aggregation characteristics.

Materials and Methods

Synthesis of nanoscale ZnO and boron Preparation of nanoscale ZnO: Nanoscale ZnO was prepared by using the oxalate decomposition technique as described by Prasad *et al.*, 2012 [3]. In brief, equimolar concentrations of zinc acetate and oxalic acids were mixed thoroughly for 3 hrs at 60 degree centigrade. The solution was then filtered and the obtained precipitation was air dried and calcined at 500 degree centigrade for 1 hr. The collected zinc oxide nano powder was used in the further experiments.

Characterization of nanoscale ZnO

UV – Vis (UV-Visible spectra) analysis

Ultraviolet–Visible (UV–Vis) spectroscopic analysis was carried out to confirm the formation and optical properties of the synthesized zinc oxide nanoparticles. The absorption spectrum was recorded using a UV–Visible spectrophotometer (UV-1800, Shimadzu, Kyoto, Japan). The nanoparticle suspension was prepared by dispersing the synthesized ZnO nanoparticles in distilled water, and the absorbance was measured over the wavelength range of 300–600 nm using a quartz cuvette with a 1 cm path length. The characteristic absorption maximum (λ_{max}) was recorded to confirm the formation of ZnO nanoparticles.

Fourier Transform Infrared (FT-IR) spectroscopy

Fourier Transform Infrared (FT-IR) spectroscopic analysis was carried out to identify the functional groups and chemical bonds associated with the synthesized zinc oxide nanoparticles. The FT-IR spectrum was recorded in the range of 400–4000 cm^{-1} using an ATR-FTIR spectrometer (IRTracer-100 AH, Shimadzu, Japan) operated at a resolution of 4 cm^{-1} . The synthesized ZnO nanoparticles were directly placed on the diamond ATR crystal and the spectra were recorded in transmittance mode. The obtained absorption bands were analysed to confirm the characteristic functional groups associated with ZnO nanoparticles.

Scanning Electron Microscopy and EDAX analysis

The surface morphology and elemental composition of the synthesized zinc oxide nanoparticles were examined using a Scanning Electron Microscope (SEM) (EVO 10, Carl Zeiss Microscopy, Cambridge, UK). A small quantity of the dried ZnO nanoparticle sample was uniformly mounted on an aluminium stub using conductive carbon tape and coated with a thin layer of gold–palladium using a sputter coater to improve electrical conductivity. The sample was subsequently observed under suitable accelerating voltage and magnification to evaluate particle shape, surface texture and aggregation pattern.

Results

Synthesis of nanoscale ZnO

Nanoscale zinc oxide particles were synthesized following the procedure described in the Materials and Methods section. The major steps involved in their preparation are schematically presented in Fig. 1. The synthesized nanonutrients were subjected to various characterization techniques and the results concerning particle size, morphology and dispersibility indicated that the prepared nanoparticles possessed suitable properties for foliar application and subsequent agricultural investigations.

Characterization of nanoscale ZnO

UV–Visible spectral analysis of nanoscale ZnO

The UV–Visible absorption spectrum of the synthesized nanoscale zinc oxide exhibited a distinct absorption maximum at approximately 370 nm (Fig. 2). This characteristic absorption band was associated with the electronic transition of electrons from the valence band to the conduction band, thereby verifying the formation of ZnO nanoparticles. The occurrence of this absorption maximum further demonstrated the nanoscale characteristics and pronounced optical response of the synthesized particles. Hence, UV–Visible spectroscopic analysis established the successful preparation of nanoscale ZnO.

Fourier Transform Infrared spectroscopy (FT-IR)

The FTIR spectrum of the synthesized zinc oxide nanoparticles was recorded in the range of 400–4000 cm^{-1} using 100 scans at a resolution of 4 cm^{-1} (Fig. 3). The spectrum exhibited high transmittance throughout most of the region, indicating the presence of only a small quantity of surface-bound organic residues. A weak absorption band observed at 2345.44 cm^{-1} was attributed to the asymmetric stretching vibration of atmospheric or surface-adsorbed CO_2 . The absence of prominent O–H, C–H and C=O absorption bands suggested the effective removal of moisture and organic precursor residues during nanoparticle preparation. A pronounced reduction in transmittance below approximately 650 cm^{-1} , extending towards 400 cm^{-1} , was associated with the stretching vibrations of Zn–O bonds in the ZnO crystal lattice. The characteristic absorption in the lower wavenumber region therefore supported the successful formation of ZnO nanoparticles with comparatively low organic contamination.

Scanning Electron Microscopy

The SEM image (Fig. 4) revealed that the synthesized nano zinc particles were predominantly irregular to nearly spherical in shape, with rough and uneven surface morphology. The particles were closely associated with one another and formed compact agglomerated clusters. The particle dimensions marked in the micrograph were 37.95, 40.08, 45.28 and 59.55 nm, indicating a size range of approximately 37.95–59.55 nm, with an average particle size of about 45.72 nm. The observed aggregation may be attributed to the high surface energy of the nanoparticles, which promotes attractive forces among the particles and leads to cluster formation. The SEM image was captured using a ZEISS scanning electron microscope at a magnification of 15,000 $\times$, an accelerating voltage of 10.00 kV and a working distance of 13.5 mm, using a secondary electron detector (SE1). The nanoscale dimensions and characteristic clustered morphology observed in the micrograph supported the successful formation of nano zinc particles. These morphological characteristics may influence their surface reactivity, dispersion, dissolution and zinc-release behaviour when used for agricultural applications.



Fig 1: Synthesis of nanoscale ZnO by oxalate decomposition technique

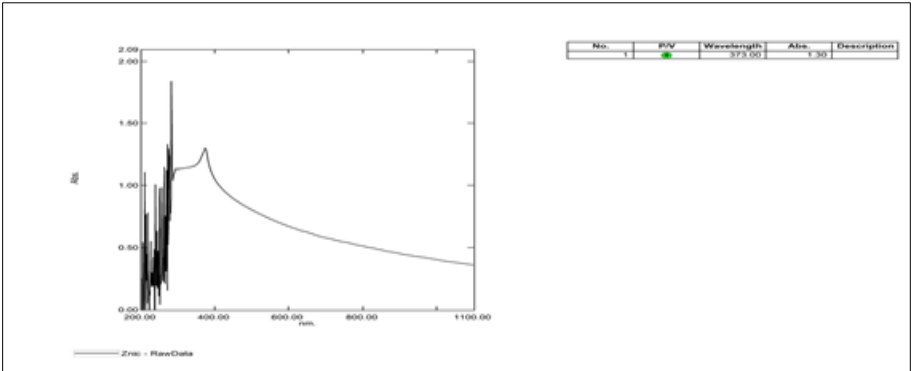


Fig 2: UV-Vis absorption peak of nanoscale ZnO

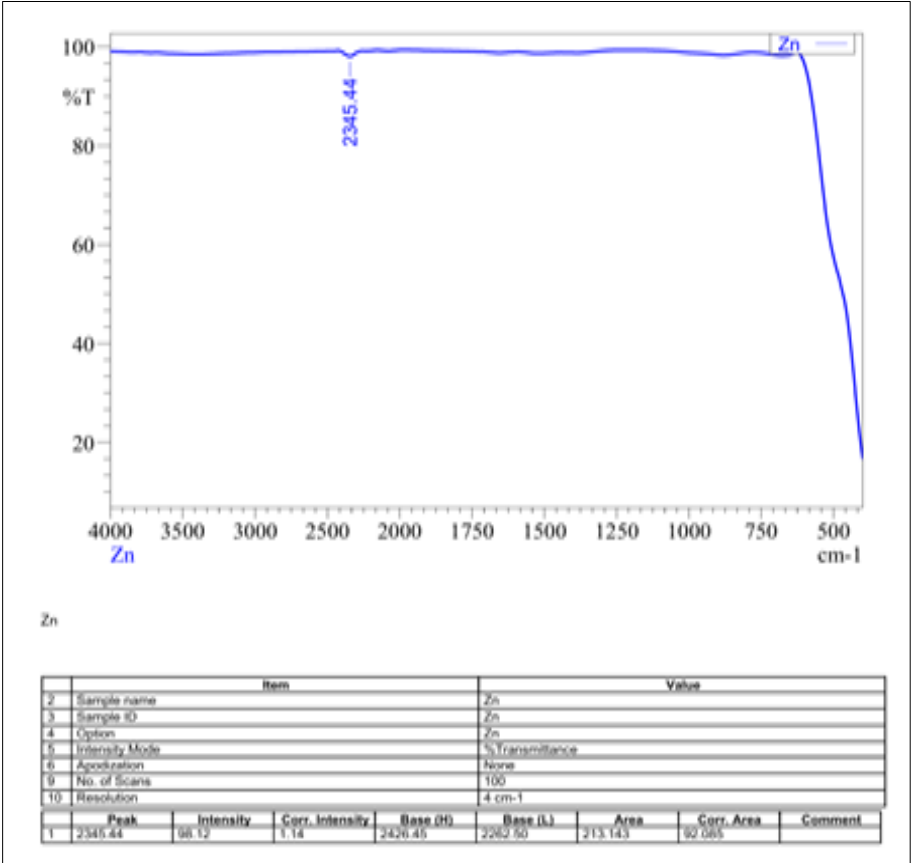


Fig 3: FTIR analysis of nanoscale ZnO

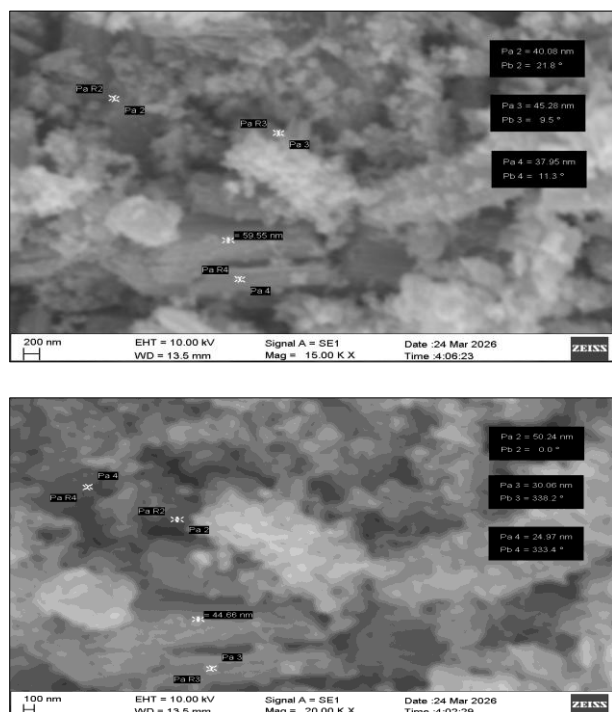


Fig 4: SEM analysis of nanoscale ZnO

Conclusion

Successful synthesis of nanoscale zinc oxide was confirmed through FTIR, UV–Visible spectroscopy and SEM analysis. The shape is crystalline in structure with hexagonal wurtzite crystal structure. The characteristic Zn–O absorption in the lower wavenumber region and the UV–Visible absorption maximum at approximately 370 nm verified ZnO nanoparticle formation. SEM analysis revealed irregular to nearly spherical particles with agglomerated morphology and sizes ranging from 37.95 to 59.55 nm, with an average size of 45.72 nm. The synthesized ZnO nanoparticles exhibited desirable nanoscale and surface characteristics, indicating their potential use in nano-fertilizer formulations for improving zinc availability, nutrient-use efficiency and sustainable crop production.

References

1. Abegunde SM, Adubiaro HO, Ishaya FA. Zinc oxide nanoparticles in smart agricultural fertilization: Current developments and future perspectives. *Hybrid Adv.* 2026;13:100637.
2. Ayenew BM, Satheesh N, Zegeye ZB, Kassie DA. A review on the production of nanofertilizers and its application in agriculture. *Heliyon.* 2025;11(1):e41243.
3. Prasad TNVKV, Sudhakar P, Sreenivasulu Y, Latha P, Munaswamy V, Raja Reddy K, *et al.* Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J Plant Nutr.* 2012;35(6):905-927.
4. Rani N, Sagar NA, Chauhan A, Mondal A. Green synthesis of ZnO nanoparticles: Characterization and emerging applications in sustainable agriculture. *Ind Crops Prod.* 2025;233:121393.
5. Ravishankar LV, Puranik N, Lekkala VVV, Lomada D, Reddy MC, Maurya AK. ZnO nanoparticles: Advancing agricultural sustainability. *Plants.* 2025;14(15):2430.
6. Swain M, Mishra D, Sahoo G. A review on green synthesis of ZnO nanoparticles. *Discov Appl Sci.* 2025;7:997.