JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Characterization and Biological Applications of Zinc Oxide nanoparticles synthesized from *M. dioica* leaves extract

V. K. Dakhure 1st , M. K. Zate 2nd, R. V. Sangvikar 3rd and B. D. Gachande 4th .

1st, 3rd & 4th Botany Research Laboratory, N.E.S.Science College, Nanded-431605,(MS),India
2nd Departments of Physics, SVKT Arts, Science and Commerce College, Nashik-422401, (MS), India

Abstract : In the present work, zinc oxide nanoparticles were successfully fabricated by using *Momordica dioica* Roxb. ex willd leaves aqueous extract as a reducing agent. The formed ZnONPs were characterised by UV-visible spectroscopy, X-ray diffraction (XRD), and SEM scanning electron microscopy. ZnONPs were confirmed by UV-visible spectra; the highest absorbance peak was found at 357 nm. The crystallite particle size was found in a range of 15.13 nm by XRD. Scanning Electron Microscopy (SEM) analysis confirms ZnONPs were granular-shaped and closely aggregated. In antioxidant activity, the IC-50 value of ZnONPs was found to be 669.46 µg/ml. Its antimicrobial activity was performed by the well diffusion method against Staphylococcus aureus and Escherichia coli. The highest antimicrobial activity of ZnONPs synthesised by *Momordica dioica* leaf extracts was found against Staphylococcus aureus (15 mm) and Escherichia coli (13 mm), respectively. The green synthesised ZnONPs have efficient antimicrobial activity against selected human pathogenic bacteria.

IndexTerms -. Nanoparticles, Antioxidant, Antimicrobial, M. dioica.

1. Introduction

Among the available large number of nanoparticles, metal oxide nanoparticles are considered to be more promising as they exhibit unique physical, chemical, and biological properties [1]. The nanoparticles obtained via the green synthesis method are found to be cost effective, non-toxic, and biodegradable in nature. This eco-friendly synthesis method reduces the use of hazardous substances as the process utilizes natural materials like leaves, roots, and flower extracts and microorganisms like bacteria, fungi, algae, etc. [2]. Nonmaterial are products processed through nanotechnologies that contain nanoparticles (NPs) on a scale ranging from 1 to 100 nm [3]. Zinc oxide is an inorganic compound with the formula ZnO. It occurs as white powder commonly known as zinc white or as the mineral zincite. The zinc oxide nanoparticles (ZnONPs) owe its unique physical and chemical properties which include adsorption of radiation, large excitation binding energy (60 eV), higher stability, wide band gap (3.37 eV), electrochemical coupling coefficient, n-type semi conductivity, high rate of chemical reaction in presence of catalyst, inexpensive luminescent material non-toxic, etc. [4]. Zinc is one of the essential micronutrients for the plant. Zinc is the major component of enzymes or cofactor of enzymes. Zinc oxide nanoparticles (ZnONPs) are important for chlorophyll production, fertilization, pollen function, and germination. Zinc oxide nanoparticles have notable optical, physical, and antimicrobial properties and so have great potential to boost agriculture [5]. The novel properties of nanoparticles are widely deployed for various applications in medicine, [6][7] cosmetics, biomedical devices, environmental remediation, electronics, photocatalysis, energy reservoirs, agriculture, automobiles, packaging, and information technology [8][9]. Zinc oxide nanoparticles are considered the most significant among the metal oxide nanoparticles for their thermal stability, robustness, low electric resistance, low cost, non-toxicity, high UV protection, and biocompatibility [10].

Momordica dioica is a wild plant that belongs to the *Cucurbitaceae* family. It is generally found during the months of June to September in India [11, 12]. *M. dioica* is monosexual; the male and female flower is borne separately [13]. Its abundance and accessibility make it a suitable and cost-effective source for obtaining leaf extracts for nanoparticle synthesis. Furthermore, biosynthesis aims to minimise the use of hazardous chemicals and energy-intensive processes. *M. dioica* leaf extract offers a sustainable and eco-friendly alternative to the traditional chemical method for synthesising ZnONPs.

2. Preparation of M. *dioica* Leaves Extract

M. dioica leaves were collected from geographical location Aundha Nagnath, Dist-Hingoli, Maharashtra (India). The *M. dioica* leaves were cleaned many times with distilled water to remove dust particles and subsequently sun dried to remove the residual moisture. For the extraction of leaves, we used the Soxhlet method shown in Fig. 1. The Soxhlet extraction method is used by many researchers [14]. The 10 gm of plant leaf powder was placed into a thimble of Soxhlet in a filter paper roll. The 250 ml of water was used as a solvent. The water was placed in the round bottom kept at heating metal. The temperature of heating metal was adjusted to the boiling point of water. After 5 cycles, the solvent present in the thimble appears to be transparent. The extract was evaporated to get a solid plant extract. The extract was stored at room temperature in order to be used for further experiments.

Figure1: Soxhlet Extraction

3. Green synthesis of ZnO Nanoparticle

In the typical synthesis of ZnO nanoparticles, leaves extract has been used as a reducing agent. *M. dioica* extract contains many phytochemicals such as alkaloids, steroids, flavonoids, etc. Such phytoconstituents are linked with Zn ions to form nanoparticles. The 10 ml of *M. dioica* leaves extract was added into 90 ml of 1 mM zinc acetate solution and kept in stirring for constant mixing under room temperature. A colour change of the mixture was noted by visual examination, confirming the synthesis of zinc oxide nanoparticles shown in Fig. 2.

4. Characterization of green Zinc Oxide nanoparticles

The characterization of biosynthesized Zn nanoparticles was carried out for different parameters, such as absorbance peak, by UV-visible spectrometer. The synthesised particle size and their morphology were studied by using a scanning electron microscope. To determine the nanoparticle structure, use XRD [15].

4.1 UV- Visible Spectroscopy Analysis

The UV-Vis spectroscopy analysis of biosynthesis ZnONPs was performed by continuous scanning from 200 to 800 nm [16]. The formation of NPs and the stability in solution were examined by UV-vis absorption spectroscopic analysis.

4.2 X-ray Diffraction Analysis

The formation and quality of synthesised particles were investigated by the X-ray diffraction technique. The sample collected from the biosynthesis of ZnO NPs using *M.dioica* leaves extract was analysed using a powder X-ray diffractometer. X-ray diffraction (XRD) is a characterization method that is used for the determination of crystallography of the particles of interest in this experiment. In this method, X-ray diffraction scanning was done in the region of 2θ from 20° to 80°.

4.3 Scanning Electron Microscopy

The scanning electron microscope (SEM) is one of the most widely used techniques used for characterization of nanoparticles. The signals that derive from electron-sample interactions reveal information about the sample, including surface morphology (particle size, shape, and texture) of the sample.

5. Antioxidant Activity of synthesized ZnONPs

Antioxidant activity of Synthesized ZnONPs of *M. dioica* leaves extract was done by the (1, 1-diphenyl-2-picryl hydroxyl) DPPH free radical scavenging method. For the activity, a 0.1 mM solution of DPPH in ethanol was prepared. This solution of DPPH (1 ml) was added to 3 ml. of *M. dioica* leaves extracts in ethanol at different concentrations (200, 400, 600, 1000 µg/ml). The mixture was shaken well and allowed to stand in a dark room for 30 min. The absorbance was measured at 517 nm by using a spectrophotometer to determine absorbance. Ascorbic acid is used as standard. The lower absorbance of the reaction mixture showed higher free radical scavenging activity [17-21]. The percent DPPH scavenging effect was calculated by using the following equation: DPPH scavenging activity (%) = $((A_c - A_t) / A_c)$ 100.

Where Ac was the absorbance of the control reading and, At was the absorbance in the presence of the test.

6. Antimicrobial Activity

The ZnO nanoparticles were biosynthesized and tested for antibacterial activity using the agar-well diffusion method. This method of testing is frequently used to evaluate antibacterial activity. Surface of Agar plates using a sterile spreader, inoculums containing 106 cfu/ml of each bacterial culture under evaluation have been spread to nutrient agar plates. After this, 8 mm-diameter wells were punched into the agar medium, filled with 100 µl of sample, and kept to diffuse for an hour at room temperature. After that, the plates were incubated for 24 hours at 37 C while upright. Positive controls were standard antibiotic streptomycin, whereas negative controls were wells with the same volume of distilled water. After incubation, the growth inhibition zones measures were measured in mm. [22].

7. Result and Discussion

7.1 Formation of ZnONPs

Synthesis of ZnONPs from *M. dioica* leaves extract conformed by their characterization. A colour change of the mixture was noted by visual observation, confirming the synthesis of zinc oxide nanoparticles shown in Fig. 2. Biosynthesis of ZnONPs was preliminary confirmed by visual observation of colourless to dark-yellow precipitate, as seen in Figure 2. Where it was determined that the Phyto constitutes denoted their electrons to ions and contributed to the stabilisation of positively charged Zn^{2+} ions; then, thermal annealing was performed for the conversion of Zn^{2+} complex ions to ZnO nanoparticles [23].

Figure 2: Color change confirmation of synthesis of ZnONPs

7.2 UV- Visible Spectroscopy Analysis

The UV-VIS absorption spectrum was observed by a JASCO UV-VIS spectrophotometer for bio reduction of zinc ions to ZnONPs mediated by *M. dioica leaf* extracts. Absorption spectra show absorbance at 357 nm (Fig. 3a), which was due to excitation in surface Plasmon vibration. This is the most significant feature of metal nanoparticles, which is due to the electron oscillations that collectively gather around the surface of metal particles. In similar studies of ZnONPs, it was mostly found that the absorbance spectra showed the peak at 300-450 nm [24-25]. The direct energy band gap was calculated using the Tauc relation $(\alpha h\nu)^2 = A(h\nu - E_g)$. Where is absorption coefficient, h is Planck's constant frequency of light used, A is constant, and E_g is energy band gap. The Fig. 3b) depicts that the direct energy band gap of ZnONPs calculated from Tauc's plot is found to be 3.10 eV, which matches the standard value.

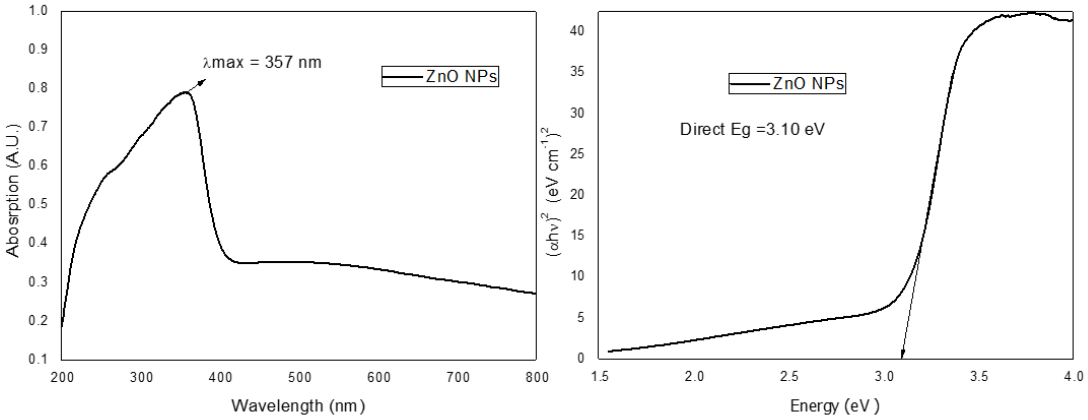


Figure 3: a) *UV-vis spectrum* b) *Tauc plot* of ZnONPs synthesized using aqueous *M.dioica* extract.

7.3 X-ray Diffraction Analysis

The crystallographic structure of *Momordica dioica* leaves extract-mediated biosynthesis of Zn-ONPs was examined by XRD analysis. As depicted in Figure 4, the formed ZnO-NPs showed seven distinguished peaks at 2θ degrees: 31.7, 34.5, 36.1, 47.4, 56.3, 63.1, and 67.9, which matched to (100), (002), (101), (102), (110), (103), and (112) planes, respectively. All outstanding diffraction peaks in XRD spectra are compatible with those recorded in the Joint Committee on Powder Diffraction Standards (JCPDS, card no. 89-7102 and JCPDS card no. 05-0664), which confirm the crystallographic Wurtzite structure. The Debye-Scherrer formula was used to calculate crystallite size [26–27]. It is given by D = kλ/βcosθ. Where D is crystallite size is Scherrer constant, λ is wavelength of x ray, β full width half maxima; θ is scanning angle. The calculated crystallite size of 15.13 nm reveals the formation of nanoparticles. All the sharp peaks in the XRD pattern depict that the ZnONPs are crystalline in nature. The presence of slight peaks in XRD spectra may be related to the crystallization of organic substances that coated the surface of ZnO-NPs.

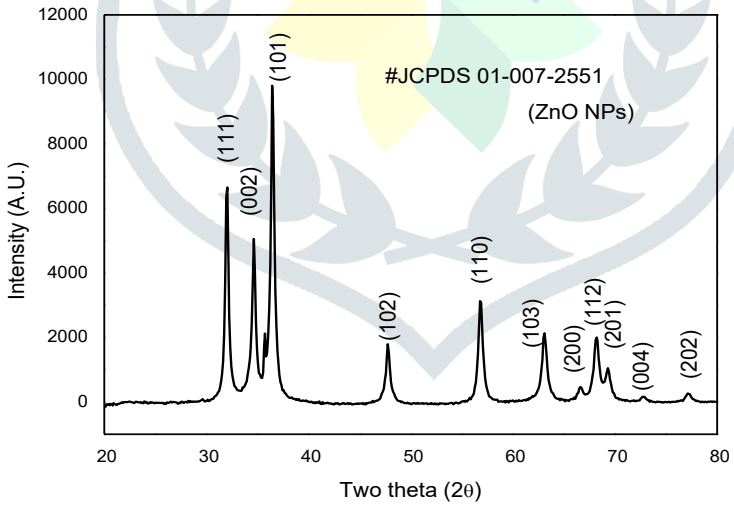
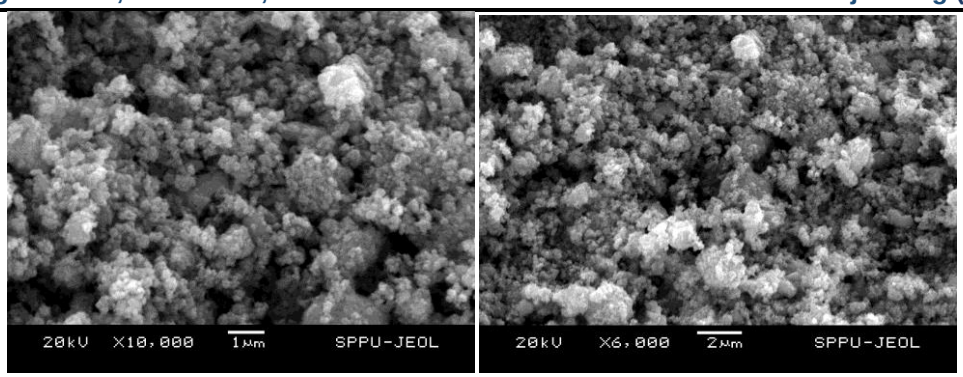


Figure 4:X-ray Diffraction Analysis of ZnONPs synthesized from *M.dioica* Leaves Extract.

7.4 Scanning Electron Microscopy

The surface morphology and size of the ZnONPs was recognized by Scanning Electron Microscope. SEM image had shown shape and size of the nanoparticles synthesized by using leaf extract of *Momordica dioica leaves.*Figure 5 (a),(b) shows the surface morphology of the zinc oxide nanoparticles synthesized by using levees extract of *M. dioica* recorded under different magnifications such as 2000 nmand1000 nm respectively. It shows mostly granular shaped and closely aggregated ZnO nanoparticles were observed. The average particle size was investigated using Image J Software and it is found in the rage of 50-120 nm [28].



(a) (b)

Figure 5: SEM image of ZnO NPs synthesized from *M. dioica* leaves extract at different scale bar (a) 2000nm, (b) 1000 nm

7.5 Antioxidant activity of Synthesized ZnO nanoparticles

Table No: 1-Antioxidant activity (DPPH Method) of biosynthesized ZnONPs from *M. dioica* leaf extract.

Sr. No.	Sample	% of Free radical scavenging activity				
		200 µl	400 µl	600 µl	800 µl	1000 µl
1	ZnONPs of MDLWE	42.55	44.34	49.3	52.97	55.05
2	L-Ascorbic acid	49.40	52.38	55.35	58.33	61.30

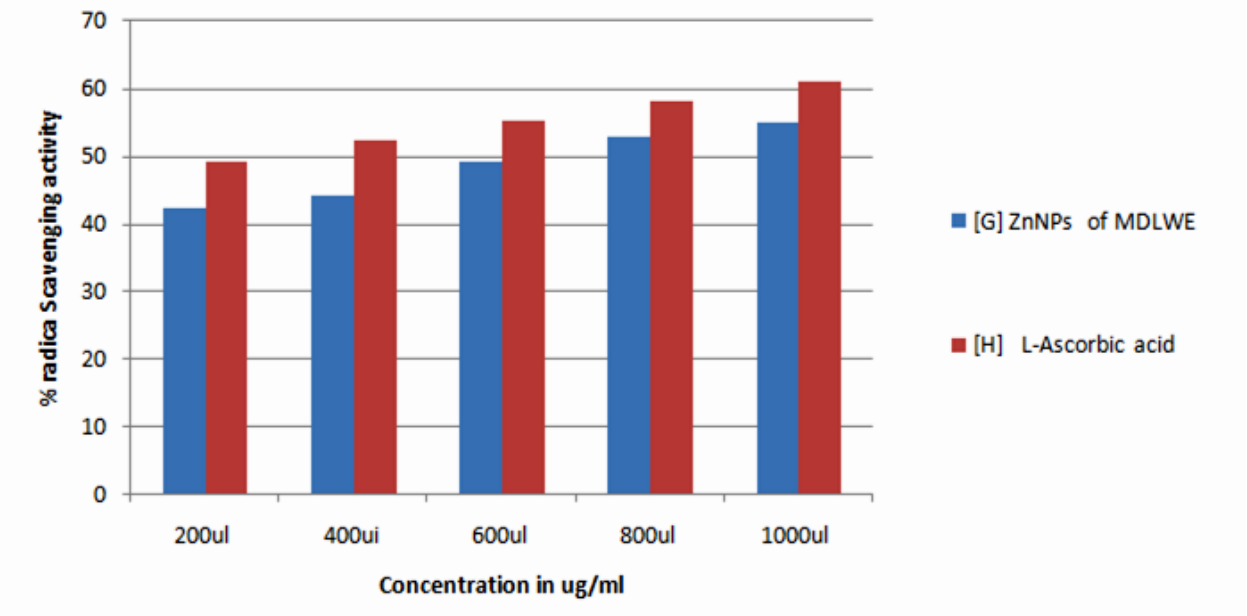


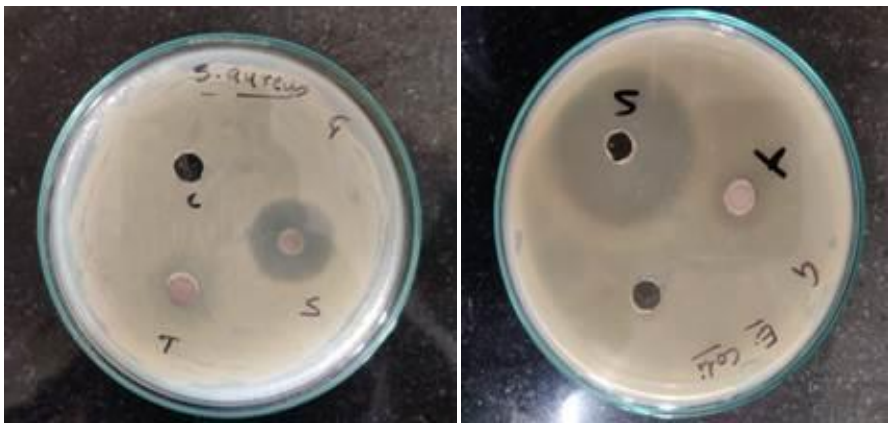
Figure 6: Antioxidant activity of ZnONPs synthesized From *M.dioica* leaf extract.

The significant antioxidant potential of ZnONPs was evaluated by a DPPH free radical scavenging assay. The antioxidant property of ZnO NPs could be attributed to functional groups present in the plant extract. Fig. 6 and Table-1 shows the DPPH radical scavenging activity of biosynthesized ZnO nanoparticles. An IC-50 value refers to the various concentrations of the sample required to scavenge 50% of the free radicals present. The IC-50 value obtained for ZnONPs was found to be 669.46 µg/ml.

Antimicrobial activity

The green-synthesized ZnO NPs exhibited substantial antibacterial activity for wide-spectrum bacteria, whereby interacting with the bacterial cell surface and its core, ZnONPs can enter inside the cells and display their bactericidal effect [29]. In this study, the antibacterial activity of biosynthesized ZnO NPs from *M. dioica* leaf extract was against two types of bacterial strains: one is gram positive *Staphylococcus aureus* (ATCC 29213) and the second gram negative *E. coli* (ATCC 25922). The diameter of the inhibition zone of biosynthesized ZnONPs of *M. dioica leaves* extract and Streptomycin as a positive control was determined using an agar-well diffusion disc and presented in Fig. 7. Biosynthesized ZnONPs showed significant antibacterial activity against the two bacterial strains compared with the positive control. Regarding the bacterial strain type, ZnONPs showed a higher bactericidal effect in gram positive strains (*S. aureus*)

compared with gram negative strains (E. *coli*). [30] Rana Abdullah Alghamdi et al. showed similar activity had been reported for green synthesized ZnONPs.



(a) **(b)**

Figure 7: Photograph of antimicrobial activity of zinc nanoparticles and standard against (a) *S. aureus and* (b) *E. coli.*

Table2: Result showing measurement of zone of inhibition formed by ZnONPs against *S.aureus* and *E.coli.*

Sr. No.	Sample name	Zone of Inhibition (mm)	
		Staphylococcus aureus	*Escherichia coli*
1	ZnONPs	15	13
2	Streptomycin	20	38

8. Conclusion:

Momordica dioica is a wild climber that grows without utilizing any fertilizer or any pesticides; it has good nutrition value because of that it is mostly significant to human health. In the present work, a simple methodology was used to achieve a green eco-friendly approach for the synthesis of Zinc nanoparticles by using *M. dioica* leaves water extracts. The green synthesized ZnONPs were characterized by UV-visible spectroscopy, XRD, and SEM. absorption peak was found at 357 nm by UV-Vis spectrophotometric measurements. The XRD analysis confirmed the crystalline structure with an average crystallite size range of 15.13 nm and the average particle size was found in the range of 50-120 nm by SEM analysis. The antioxidant activity of ZnONPs determined by using the DPPH method shows IC 50 value of ZnO nanoparticles was found to be 669.46 µg/ml. The antimicrobial activity of Zinc nanoparticles synthesized by *Momordica dioica* leaves extracts was found against *S. aureus* (15mm) and *E. coli* (13 mm) respectively. As a result, the green synthesized ZnONPs could be of immense use in the medical field for their efficient antioxidant and antimicrobial function.

References

1. Demissie, M. G., Sabir, F. K., Edossa, G. D., &Gonfa, B. A. 2020. Synthesis of Zinc Oxide Nanoparticles Using Leaf Extract of Lippiaadoensis (Koseret) and Evaluation of Its Antibacterial Activity. *Journal of Chemistry*, *2020*, 1–9. https://doi.org/10.1155/2020/7459042.
2. Jayachandran, A., T.R., A., & Nair, A. S. 2021. Green synthesis and characterization of zinc oxide nanoparticles using Cayratiapedata leaf extract. *Biochemistry and Biophysics Reports*, *26*. https://doi.org/10.1016/j.bbrep.2021.100995
3. Rahman, F., Majed Patwary, M. A., Bakar Siddique, Md. A., Bashar, M. S., Haque, Md. A., Akter, B., Rashid, R., Haque, Md. A., &Royhan Uddin, A. K. M. (2022). Green synthesis of zinc oxide nanoparticles using *Cocos nucifera* leaf extract: characterization, antimicrobial, antioxidant and photocatalytic activity. *Royal Society Open Science*, *9*(11). https://doi.org/10.1098/rsos.220858
4. Umamaheswari, A., Prabu, S. L., John, S. A., &Puratchikody, A. (2021). Green synthesis of zinc oxide nanoparticles using leaf extracts of Raphanus sativus var. Longipinnatus and evaluation of their anticancer property in A549 cell lines. *Biotechnology Reports*, *29*, e00595. https://doi.org/10.1016/j.btre.2021.e00595
5. Ukidave, V. V., & Ingale, L. T. (2022). Green Synthesis of Zinc Oxide Nanoparticles from Coriandrum sativum and Their Use as Fertilizer on Bengal Gram, Turkish Gram, and Green Gram Plant Growth. *International Journal of Agronomy*, *2022*, 1–14. https://doi.org/10.1155/2022/8310038
6. Kulkarni, S., Sawarkar Mahavidyalaya, S., &Shirsat, M. (2015). Optical and Structural Properties of Zinc Oxide Nanoparticles. *International Journal of Advanced Research in Physical Science (IJARPS)*, *2*(1). https://www.arcjournals.org/pdfs/ijarps/v2-i1/3.pdf
7. Kalpana, V. N., & Devi Rajeswari, V. (2018). A Review on Green Synthesis, Biomedical Applications, and Toxicity Studies of ZnO NPs. *Bioinorganic Chemistry and Applications*, *2018*, 1–12. https://doi.org/10.1155/2018/3569758
8. Kebede Urge, S., Tiruneh Dibaba, S., & Belay Gemta, A. (2023). Green Synthesis Method of ZnO Nanoparticles using Extracts of Zingiber officinale and Garlic Bulb (Allium sativum) and Their Synergetic Effect for Antibacterial Activities. *Journal of Nanomaterials*, *2023*, e7036247. https://doi.org/10.1155/2023/7036247
9. Abbasi, B. A., Iqbal, J., Ahmad, R., Zia, L., Kanwal, S., Mahmood, T., Wang, C., & Chen, J.-T. (2019). Bioactivities of Geranium wallichianum Leaf Extracts Conjugated with Zinc Oxide Nanoparticles. *Biomolecules*, *10*(1), 38. https://doi.org/10.3390/biom10010038
10. Abdol-Majid Cheperli, Majid Mokaber-Esfahani, Akram Taleghani, & Farhad bahalkeh. (2022). Biosynthesis, characterization and antimicrobial activities of zinc oxide nanoparticles from leaf & seed extracts of Malva neglecta Wallr. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-1286975/v1
11. Kapadia, P., Newell, A. S., Cunningham, J., Roberts, M. R., & Hardy, J. G. (2022). Extraction of High-Value Chemicals from Plants for Technical and Medical Applications. *International Journal of Molecular Sciences*, *23*(18), 10334. https://doi.org/10.3390/ijms231810334
12. Bhoye, S. B. a. B. a. N. (2021). Spine Gourd (Momordica dioica) Article ID: 10735. *Agriculture & Food: E-Newsletter, ISSN: 2581-8317*.
13. M. G. W. K., & Dahanayake, N. (2021). Momordica dioica Roxb (Spine Gourd)- An underutilized vegetable and medicinal plant in Sri Lanka. *International Journal of Minor Fruits, Medicinal and Aromatic Plants*, *7*(2), 100–104. https://doi.org/10.53552/ijmfmap.2021.v07ii02.011
14. Bawara, B., Dixit, M., Chauhan, N., Dixit, V., Saraf, D., Saraf, D. K., Gour, H., & Sagar, V. (2010). Phyto-pharmacology of Momordica dioica Roxb. ex. Willd: A Review. *International Journal of Phytomedicine*, *2*, 1-09. https://doi.org/10.5138/ijpm.2010.0975.0185.02001
15. Aparna, P., & Vastrad, J. (2022). Green waste mediated Zinc Oxide nanoparticles with citrus peel. In *~ 1 ~ the Pharma Innovation Journal*.
16. Sirohi Sandeep, Chinta Koteswara Rao, Andanamala Vijay Rajesh, Talapudi Sruti, DV Surya Prakash (2022), Studies on Characterization and Optimization Parameters of Zinc Oxide Nanoparticles synthesis'Int.J Cur res Rev, Vol-14,issue3.
17. Tailor Chandra Shekhar and Goyal Anju (2014) "Antioxidant activity by DPPH radical scavenging method of ageratum conyzoides," *American Journal of Ethnomedicine*, vol. 1, Art. no. 4.
18. A. Athavale, N. Jirankalgikar, P. Nariya, and S. De (2012) "Evaluation of in-vitro antioxidant activity of panchagavya: a traditional ayurvedic preparation," *International journal of pharmaceutical sciences and research*, vol. 3, Art. no. 8.

19. P. Poonia, J. Niazi, G. Chaudhary, and A. Kalia, "In-vitro antioxidant potential of jasminummesnyi hance (leaves) extracts,"(2011) *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, vol. 2, Art. no. 1.
20. S. Faujdar, S. Nain, and A. Kalia,(2013) "Antioxidant activity and estimation of total phenolic content of Momordica balsamina," *Int J Adv Res*, vol. 2, Art. no. 2.
21. N. Saeed, M. R. Khan, and M. Shabbir,(2012) "Antioxidant activity, total phenolic and total flavonoid contents of whole plant extracts Torilisleptophylla L," *BMC Complementary and Alternative Medicine*, vol. 12, no. 1.
22. M. K. Pandey, G. Singh, R. K. Sharma, and S. Lata,(2011), "Antibacterial activity of eclipta alba (l.) hassk,". Journal of Applied Pharmaceutical Science 01 (07): 104-107.
23. M. T. Yassin, A. A.-F. Mostafa, A. A. Al-Askar, and F. O. Al-Otibi,(2022) "Facile Green Synthesis of Zinc Oxide Nanoparticles with Potential Synergistic Activity with Common Antifungal Agents against Multidrug-Resistant Candidal Strains," *Crystals*, vol. 12, no. 6, p. 774.
24. M. M. Chikkanna, S. E. Neelagund, and K. K. Rajashekarappa,(2018) "Green synthesis of Zinc oxide nanoparticles (ZnO NPs) and their biological activity," *SN Applied Sciences*, vol. 1, no. 1.
25. E. F. El-Belely *et al.*,(2021) "Green Synthesis of Zinc Oxide Nanoparticles (ZnO-NPs) Using Arthrospira platensis (Class: Cyanophyceae) and Evaluation of their Biomedical Activities," *Nanomaterials*, vol. 11, no. 1, p. 95.
26. A. Fouda, S. EL-Din Hassan, S. S. Salem, and T. I. Shaheen,(2018) "In-Vitro cytotoxicity, antibacterial, and UV protection properties of the biosynthesized Zinc oxide nanoparticles for medical textile applications," *Microbial Pathogenesis*, vol. 125, pp. 252–261.
27. S. Faisal *et al.*(2021)"Green Synthesis of Zinc Oxide (ZnO) Nanoparticles Using Aqueous Fruit Extracts of Myristica fragrans: Their Characterizations and Biological and Environmental Applications," *ACS Omega*, vol. 6, no. 14, pp. 9709–9722.
28. J. Sujatha, S. Asokan, and S. Rajeshkumar,(2018) "Antidermatophytic activity of green synthesised zinc oxide nanoparticles using Cassia alata leaves," *The Journal of Microbiology, Biotechnology and Food Sciences*, vol. 7, Art. no. 4.
29. R. Hamed, R. Z. Obeid, and R. Abu-Huwaij,(2023) "Plant mediated-green synthesis of zinc oxide nanoparticles: An insight into biomedical applications," *Nanotechnology Reviews*, vol. 12, Art. no. 1.
30. Rana Abdullah Alghamdi *et al.*(2023) "Biogenic Zinc oxide nanoparticles from Celosia argentea: toward improved antioxidant, antibacterial, and anticancer activities," *Frontiers in bioengineering and biotechnology*, vol. 11.doi: https://doi.org/10.3389/fbioe.2023.1283898.