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SUSTAINABLE PLANT GROWTH PROMOTION AND SEED GERMINATION VIA FICUS EXASPERATE LEAF EXTRACT, CHARACTERIZATION OF GREEN SYNTHESIZED MAGNESIUM OXIDE NANOPARTICLES

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ABSTRACT

An essential mineral for plants, magnesium (Mg) is necessary for growth, metabolism, enzyme activity regulation, and general physiological processes. This study looked into the effectiveness of Mg NPs' antioxidant capacity after synthesizing them using leaf extract from the *Ficus exasperata* plant. The produced nanoparticles' stability-related and morphological properties were discovered through their characterization. UV-visible spectrophotometry was used to analyze the absorption spectra in the 200–800 nm range. The nanomaterial's size, determined by scanning electron microscopy (SEM), was 50 nm. Elemental analysis via energy dispersive X-ray (EDX) confirmed the presence of magnesium with an estimated magnesium concentration of 24.46%. *Cicer arietinum* plants exhibit higher average heights, growing to 750 µg/mL (18.3 cm), with higher average root lengths growing to 750 µg/mL (12.0 cm) and higher average leaf widths growing to 1000 µg/mL (1.4 cm) in comparison to 0.9 cm in blank soils and other concentrations. Utilizing plant leaf extract, biogenic production of magnesium nanoparticles provides an environmentally responsible and sustainable method of managing agricultural nutrient levels.

Keywords: Magnesium Nanoparticles, *Ficus exasperata*, SEM, EDX, Bengal Gram Seed Germination, and Growth Promotion Activity.

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INTRODUCTION

The growing demand for sustainable practices in agriculture and nanotechnology has triggered researchers to explore herbal options for synthetic chemical compounds. among the many plant species investigated for their ability to promote ecological balance, *Ficus exasperata* (hard-leaved fig) stands out due to its rich bioactive compound profile and its numerous applications in agriculture and nanomaterials synthesis. The leaf extract of *Ficus exasperata* has won popularity for its ability to beautify plant growth, stimulate seed germination, and enable the inexperienced synthesis of nanoparticles, especially magnesium oxide (MgO) nanoparticles.[1,2] Plant increase regulators (PGRs) from natural sources are increasingly being used as sustainable alternatives to chemical fertilizers and insecticides. *Ficus exasperata* leaf extract is rich in phenolic acids, flavonoids, and alkaloids, compounds known for their robust increase-promoting and pressure-alleviating properties. those phytochemicals have been shown to beautify various physiological approaches in flowers, such as root development, shoot elongation, leaf growth, and ordinary biomass production.[3,4] The antioxidant residences of these compounds additionally play a vital function in mitigating oxidative stress in flora, supporting them to thrive under suboptimal environmental situations such as drought, high salinity, or pathogen assault.[5,6] Seed germination is a vital degree in plant development, and enhancing seed viability and vigor is vital for sustainable agricultural practices. herbal stimulants, such as *Ficus exasperata* leaf extract, have been shown to decorate seed germination and seedling establishment, in particular below-pressure situations.[7-9] In current years, seed priming with plant extracts has emerged as a widely researched method to beautify crop productivity. research has validated that seed treatment with *Ficus exasperata* leaf extract extensively improves germination rates in a selection of plants, contributing to quicker seedling emergence and stronger root structures.[10] Those herbal increase enhancers are especially valuable in organic farming structures, where using artificial chemical substances is restrained, and keeping soil fitness and biodiversity is a priority.[11]

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Magnesium oxide (MgO) nanoparticles, especially, have garnered big attention due to their wide range of programs, which include catalysis, drug shipping, antimicrobial dealers, and water purification.[12] MgO nanoparticles synthesized in the usage of *Ficus exasperata* leaf extract have proven quite a number of useful houses. those nanoparticles showcase vast antimicrobial, antioxidant, and anticancer sports, making them ideal applicants for biomedical and environmental applications.[13] For example, MgO NPs were studied for his or her potential in water treatment, wherein they could effectively cast off heavy metals and natural pollution from infected water. additionally, inside the discipline of agriculture, inexperienced-synthesized MgO nanoparticles have been explored for their position as natural insecticides, which could help in reducing the reliance on artificial agrochemicals.[14]

EXPERIMENTAL

Sampling and Preparation of Leaf Extracts

Green synthesis begins with collecting *Ficus exasperata* stems from Rajahmundry, East Godavari, Andhra Pradesh authenticated under SRR-CVR/2020-21/Bot/62. After cleaning 50 g sample of the sieved material is mixed with 250 mL of de-ionized water, heated to 60°C, and boiled for 15 minutes. The extract is filtered.

Green Synthesis of Magnesium Nanoparticles (Mgo-NPS).

Ficus exasperata bark extract, rich in hydroxyl and carbonyl groups, is used to synthesize magnesium oxide nanoparticles. A 0.1 M magnesium nitrate solution is mixed with the extract, followed by sodium hydroxide addition to induce precipitation. The product is washed and calcined at 873 K, yielding pure nanoparticles sustainably.

Characterization of (Mgo-NPS)

The (MgONPs) utilizing *Ficus exasperate* leaf extract underwent comprehensive characterization employing various analytical techniques. UV-visible spectrophotometry within the range of 200–800 nm using a Techcomp-2301 spectrophotometer equipped with Hitachi software. Scanning Electron Microscopy (SEM) operated with a CARL ZEISS SUPRA 55 GEMIN model Energy Dispersive X-ray Spectroscopy (EDX) JEOL JEM-2100F.

RESULTS AND DISCUSSION

The synthesis of MgONPs was confirmed by a color change in the magnesium solution and precipitate formation after adding *Ficus exasperata* stem extract. The initial magnesium nitrate concentration significantly influenced nanoparticle yield, with higher concentrations (1.0 M, 0.1 M, and 0.01 M) promoting increased supersaturation and yield (Fig.-1). An absorption peak at 270 nm, characteristic of MgONPs synthesized from the extract, aligns with the typical nanoparticle absorption range of 250–360 nm.

a b c

Fig.-1(a-c): Change in Color and Yield Observed with MgONPs Solution using *Ficus exasperate* Stem Extract

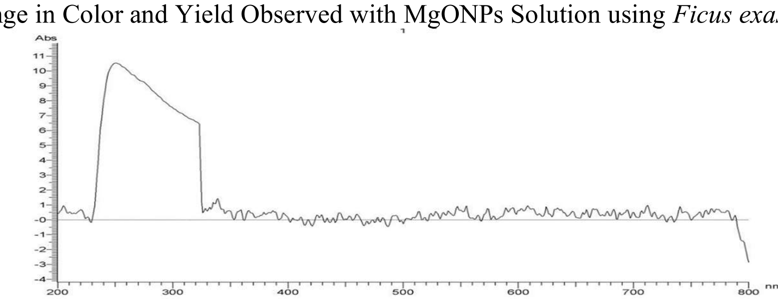

Fig.-2: UV Spectra of Synthesized MgONPs Solution using *Ficus exasperate* Stem Extract

Scanning Electron Microscope (SEM) Micrographs Analysis of Synthesized MgONPs

Figure-3 shows SEM images of MgONPs as irregularly shaped particles averaging ~50 nm, with non-uniform distribution and agglomeration. This is influenced by precursor concentration and bioactive metabolites in the *Ficus exasperata* stem extract, which enhance it is reducing capacity, making it ideal for MgONP biosynthesis.

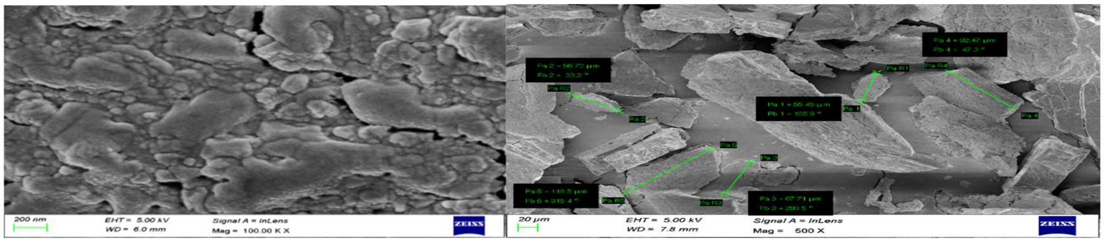

Fig.-3: Scanning Electron Microscope (SEM) Micrographs of MgONPs Synthesized using *Ficus exasperata*leaves Extract

Energy Dispersive X-Ray (EDX) Analysis of Synthesized MgONPs

EDX analysis revealed the elemental composition of MgONPs: magnesium (24.46%), oxygen (45.57%), sulfur (18.27%), potassium (5.25%), chlorine (4.22%), and sodium (1.83%). Sodium, sulfur, and potassium presence are likely due to the plant extract or precursor impurities, including 5% NaOH used in synthesis. A strong signal at 3.3 keV confirmed magnesium and organic plant biomaterials on the nanoparticle surface.

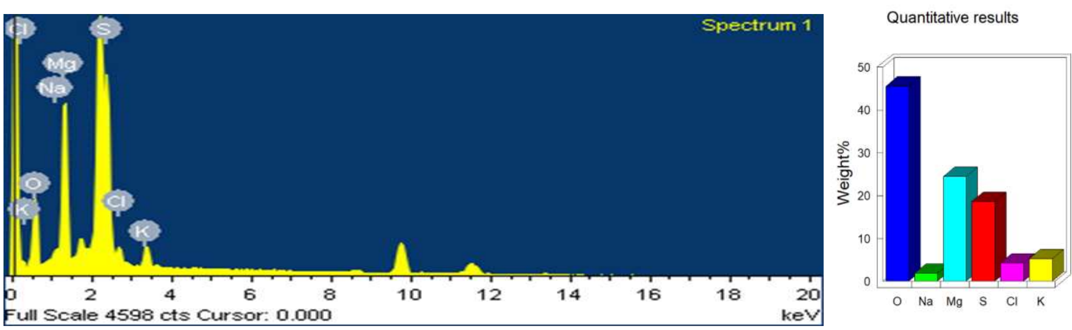

Fig.-4: Energy Dispersive X-ray (EDX) Spectra and Quantitative Elemental Results of MgONPs Synthesized using *Ficus exasperata*leaves Extract

Application of MgONPs in Seed Germination of *Cicer Arietinum* (Bengal gram)

This study highlights the potential of MgONPs as growth promoters in agriculture, significantly enhancing seed germination and growth compared to a blank sample. The improvement is linked to enhanced nutrient uptake, water absorption, and root development. Soil with 750 µg/mL MgONPs showed the highest growth (100%) in *Cicer arietinum* sprouts, outperforming 100 µg/mL (80%), 250 µg/mL (85%), and blank soil (90%). Figures-5 and 6, along with Table-1, illustrate the dose-dependent effects of MgONPs on seed germination and growth, emphasizing their potential for sustainable crop production.

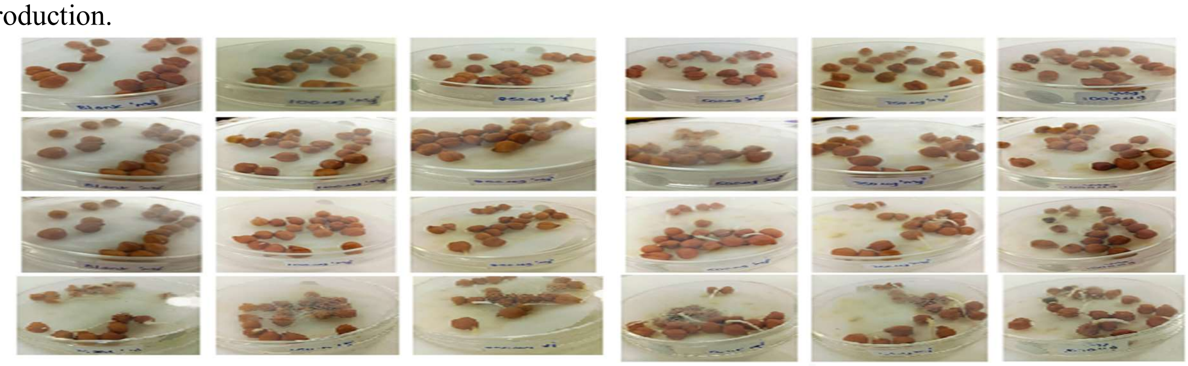

Fig.-5: Impact of MgONPs Concentration on Germination of Cicer Arietinum Seeds at 0 hours (1st row),24 hours(2nd row), and 48 Hpurs(3rd row) Respectively

Development Plants Parts of *Cicer arietinum* Bengal gram) Plant

Green-synthesized MgONPs were applied to *Cicer arietinum* at varying concentrations to evaluate growth effects over 10 days. Plants treated with MgONPs showed intense green foliage, indicating increased chlorophyll content due to magnesium's role in photosynthesis. MgONPs also enhanced structural integrity by strengthening cell walls and reducing brittleness in stems. Fertilized plants outperformed controls in growth percentage, plant height, root length, and leaf width. Soil with 750 µg/mL MgONPs showed the highest growth, suggesting it is the optimal concentration for *Cicer arietinum* cultivation. The growth of Cicer arietinum plants in different MgONPs concentrations was assessed. The highest plant growth (18.3 cm) occurred at 750 µg/mL, followed by 1000 µg/mL (17.8 cm), 100 µg/mL (16.9 cm), 250 µg/mL (16.7 cm), and the lowest growth at blank (15.3 cm).

Table-1: Results of Growth Percentage of MgONPs on of Cicer Arietinum Seeds

MgONPs concentration In µg/ml	No Plants Grown	Growth Percentage
Blank	18	90 %
100	18	80%
250	20	85%
500	17	90%
750	16	100%
1000	18	90%

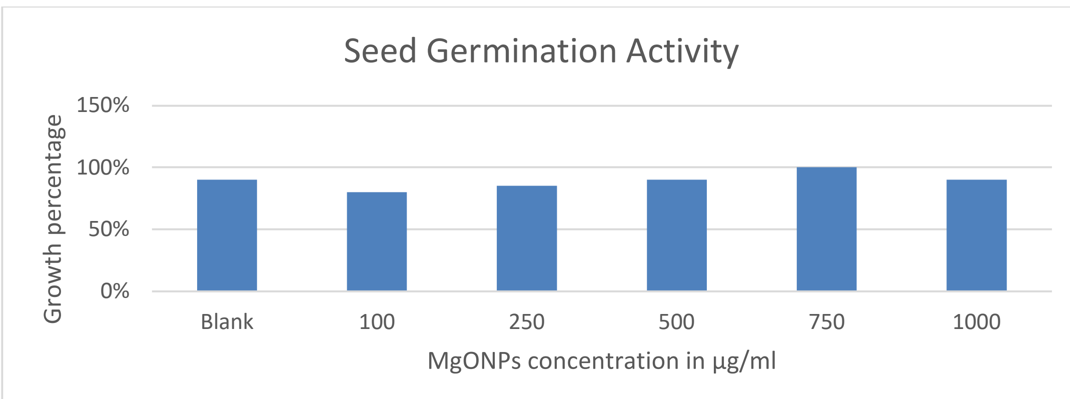

Fig.-6: Comparison of Seed Germination Percentage of *Cicer Arietinum* at different Concentrations

For root length, plants at 750 µg/mL showed the highest growth (12.0 cm), compared to blank (5.9 cm), 100 µg/mL (6.2 cm), 250 µg/mL (7.4 cm), 500 µg/mL (7.5 cm), and 1000 µg/mL (7.1 cm). Regarding leaf width, 1000 µg/mL had the widest leaves (1.4 cm), followed by 750 µg/mL (1.3 cm), 250 µg/mL (1.2 cm), 100 µg/mL (1.1 cm), 500 µg/mL (1.0 cm), and blank (0.9 cm). Overall, MgONP concentrations of 500 µg/mL and above promoted significant plant growth, with 750 µg/mL being optimal. These results highlight the importance of root development and suggest that MgONPs can enhance plant resilience, particularly under drought stress. This study provides new insights into the potential of green synthesized MgONPs for seed germination and plant growth promotion.

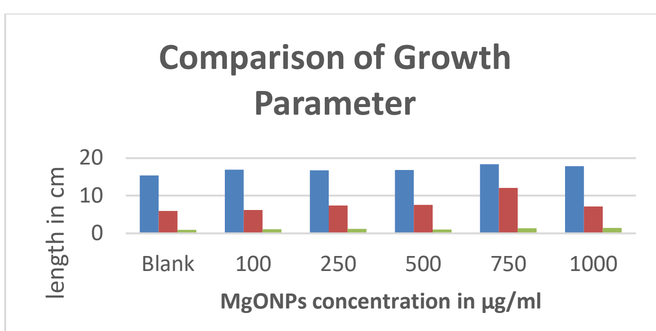

Fig.-7: Comparison of Growth Parameter of MgONPs on *Cicer arietinum* Plant

Table-2: Results and Comparison of Growth Parameter of MgONPs on *Cicer arietinum* Plant

MgONPs concentration In μg/ml	The average height of the plant in cm	Height of the plant			Average Root length in cm	Average Leaf width in cm
		Height	Moderate	Low		
Blank	15.3	20.5	15.3	8.0	5.9	0.9
100	16.9	17.6	16.9	9.2	6.2	1.1
250	16.7	19.9	16.7	9.5	7.4	1.2
500	16.8	20.5	16.8	10.0	7.5	1.0
750	18.3	21.5	18.3	10.0	12.0	1.3
1000	17.8	20.5	17.8	7.0	7.1	1.4

Fig.-8: Impact of MgONPs Concentration on Germination of *Cicer arietinum* Seeds at 1 day (1st row), 4 days (2nd row), and 10 days (3rd row) respectively

Fig.-9: Growth Comparison of Average Plants with Different Concentrations of MgONPs on *Cicer arietinum* (Bengal gram) Plant

CONCLUSION

The synthesized MgONPs exhibited agglomeration and irregular shapes ranging from 20 to 70 nm, as observed through scanning electron microscopy (SEM). This size range suggests good uniformity and makes them suitable for foliar application, facilitating efficient absorption by plant tissues. The presence of functional groups responsible for nanoparticle capping and stabilization was also noted. Elemental analysis confirmed the presence of magnesium and sodium, with magnesium constituting more than 24.46% of the nanoparticle composition. The significant growth observed in seeds treated with MgONPs at various concentrations further emphasizes the positive impact of nanotechnology on the germination of seeds and early plant maturing. This suggests that nanoparticle application may serve as an effective strategy to improve seedling establishment and enhance crop yield. In conclusion, the study highlights the potential of MgONPs in agriculture, demonstrating their ability to promote seed germination and foster early plant growth.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

S. Lakshmi Tulasi conducted the research and writing of the manuscript, analyzed the data, performed initial drafting of the manuscript, executed the experimental works, and analyzed data. The research profile of the author can be verified from their ORCID id given below:

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