GREEN SYNTHESIS OF ZINC OXIDE NANOPARTICLES AND ITS APPLICATION AS A GREEN FERTILIZER IN AGRICULTURE

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ABSTRACT

Soil fertility, quality and improving crop productivity with fertilizers is a critical problem in agriculture. The nutrition of agriculture crops relies on traditional chemical fertilizers, the production of which is expensive and still depends on fossil-fuel consumption, with a harmful effect on humans and global environment. In order to solve this problem, fertilizers must become environmentally friendly and with high nutritional content. Nanotechnology is a promising alternative method. Nanofertilizers provide favourable nutrition by their strong potential to increase nutrient proficiency and protection from leaching into groundwater; its balanced nutrient supply and biodegradability stimulates the growth of crops and improves the quality and production. Zinc is an essential micronutrient for the growth and developments of plants, but it is the most commonly deficient micronutrient in soils. In order to overcome the problem of zinc deficiency in soils, this study carried out a synthesis of ZnO nanoparticles (NPs) by green synthesis method using aqueous extract of the neem tree (*Azadirachta indica*) and characterisation by UV-visible spectrophotometer and SEM analysis. These synthesized NPs were applied as nanofertilizers and their effect on the growth of the common plant *Triticum aestivum* L. was tested. An improvement in plant growth was achieved by the application of ZnO NPs mediated nanofertilizers. From this study, it can be concluded that ZnO NPs are a promising alternative for managing zinc deficiency in soil and increasing the plant productivity.

Keywords: *biological synthesis, nanofertilizer, SEM analysis, UV-visible spectroscopy, ZnO NPs*

INTRODUCTION

Plant-mediated nanoparticles (NPs) synthesis is an innovative method with numerous applications in agriculture, food production, and medicine. This strategy also offers the advantage of extending the life of NPs due to the physiochemical features of plant-based NPs, which overcomes the negative aspects of conventional chemical and physical NPs synthesis methods. Proteins, vitamins, coenzyme-based intermediates, phenols, flavonoids, and carbohydrates are some of the biomolecules and metabolites that plants have, providing functional groups, such as hydroxyl, carbonyl, and amine which react with metal ions to reduce their size to the nanoscale [1]. Flavonoids are primarily responsible for the reduction of metal ions into NPs. These molecules not only help in the bioreduction of ions to nanoscale sizes, but they also help to cap the nanoparticles, which is crucial for stability and biocompatibility [2]. Metal ions can be reduced into NPs by reducing agents such as phenolic compounds, sterols, and alkaloids in a single reaction [3]. Many metals were used for the improvement of agriculture, food, medicinal aspects due to their effectiveness.

Zinc oxide (ZnO) is one of the most effective agents among other nanostructure due to its versatility. An extensive study shows that controlled oxygen vacancies can manipulate ZnO's optical, surface, and electronic properties. ZnO has applications in different areas, such as photocatalysis, gas sensor, biosensor, antibacterial agent, and supercapacitor [4]. Synthesis of ZnO NPs is carried out using chemical and physical methods. The mechanical synthesis of ZnO nanostructure with desired characteristics was carried out. Various approaches are used for synthesis of ZnO NPs. Green synthesis of ZnO NPs is a cost-effective and eco-friendly method [5]. In green synthesis, compounds obtained from various parts of the plant, such as the leaves, roots, stem, fruit, and flowers, are used in biological synthesis. Complex phytochemical compounds, such as phenol, alcohol, terpenes, saponins, and proteins are found in certain plant extracts and serve as reducing and capping agents in the synthesis phase [6]. The size of NPs is also affected by the plant form or source species from which the plant extract is used for NP synthesis. The average size of nanoparticles was 25 - 40 nm and 13.86 nm, respectively, when *Aloe barbadensis* and *Ocimum tenuiflorum* were used as reducing agents for the green synthesis of ZnO nanoparticles [7]. ZnO NPs synthesized with leaf extracts of *Passiflora caerulea*, *Scadoxus multiflorus*, and *Camellia sinensis*, for example, have shown various applications. Numerous studies have been carried out to check the effect of ZnO NPs on plant growth. The studies concluded that after the application of ZnO NPs, the plant parameters, such as root, shoot length, and chlorophyll content are increased, and the soil enzyme activity enhances the plant growth. The enhancement effect of ZnO NPs is appreciated and applied in agriculture practice to increase plant growth [8].

This study revealed the synthesis of ZnO NPs through neem tree (*Azadirachta indica*) extract and application as antimicrobial agents and nanofertilizers to improve plant quality.

MATERIALS AND METHODS

Media, chemicals, and reagents

The media, MacConkey's agar, was purchased from Himedia. Zinc acetate was analytical grade. The experiments were carried out in double distilled water and performed in triplicate.

Synthesis of nanoparticles

In the synthesis of ZnO nanoparticles, extracts of the neem tree (*Azadirachta indica* A. Juss.), the member of the mahogany family (*Meliacaea*e), were used as described by [9]. Fresh neem leaves were taken and treated with $HgCl_2$ followed by deionized water, then cut into small pieces and boiled for 30 min at 60 - 80 °C and stirred with a magnetic stir. The solution was filtered using filter paper and plant extract was collected. 0.1 M zinc acetate was used for the solution of metal ions. The leaves extract and metal ion solution were mixed into a beaker and put on the magnetic stir for 3 - 4 h until precipitation appeared at 60 °C. After the precipitate had been formed, the mixture was centrifuged for 10 min at 3000 rpm to remove the particles from the solution. The particles were collected and dried at 100 °C in a hot air oven before being stored at a low temperature for further processing. Figure 1 shows the synthesis procedure.

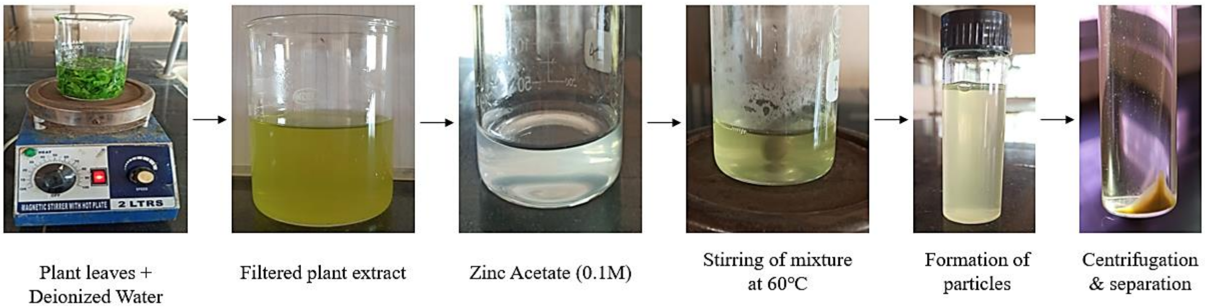

Figure 1. Green synthesis of ZnO NPs through *Azadirachta indica* extract

Characterization of nanoparticles

UV-visible spectrophotometer analysis

UV-visible spectrophotometer analysis was performed to check the higher absorption. UV-visible spectroscopy of the colloidal solution in the 200 - 700 nm range was used to test the reduction of Zn^{+2} to ZnO NPs. For baseline correction, a blank solution was first used in the spectrum detection range from 200 to 700 nm.

Scanning electron microscopy (SEM) analysis

SEM analysis was performed to confirm the size of the nanoparticles. Using standard methods, areas between 1 to 5 µm were photographed in the scanning mode. Samples were submitted to central university of Gujarat, Gandhinagar for analysis.

Application of synthesised ZnO NPs

Nanofertilizers

The ZnO NPs were applied as nanofertilizers to check the effect on plant growth. The efficiency of NPs was tested on wheat (*Triticum aestivum* L.). Plants were grown in containers to examine plant growth. Two separate containers were used, one without additional fertilizer and the other with green synthesized NPs. Containers were placed on the spots with favourable conditions for plant growth. Weekly monitoring of plants was carried out by measuring the physical condition of plants and the length of root and shoot. After the 21 days, the root length was measured.

RESULT AND DISCUSSION

Characterization of ZnO NPs

Characterization of ZnO NPs was carried out by UV-visible spectrophotometer analysis. The results are shown in Figure 2. The peak at 342 nm confirms synthesized ZnO NPs. The SEM analysis of ZnO NPs was performed to check the size and shape of nanostructures. Results are shown in Figure 3. The similar spectra were also observed in a study performed by [10].

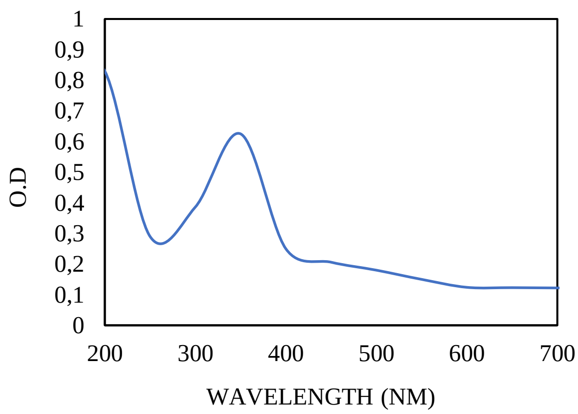

Figure 2. UV-visible spectrophotometer analysis of ZnO NPs

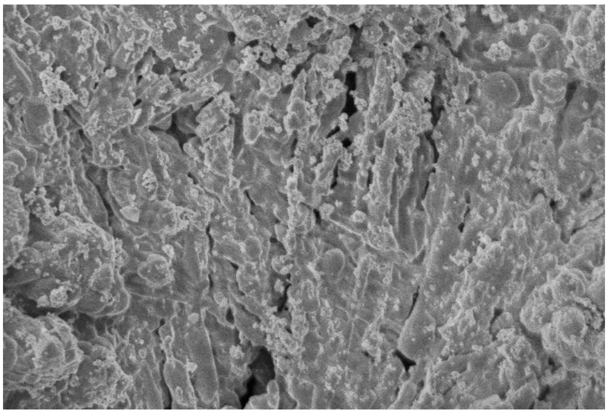

Figure 3. SEM analysis of ZnO NPs

Nanofertilizers

ZnO NPs are widely applied in agricultural soils to enhance the plant growth and increase soil fertility. This study also focused on the synthesis of ZnO NPs and its application as nanofertilizers. ZnO NPs were applied as nanofertilizers to check their effect on wheat (*Triticum aestivum L.*). The growth of plant was observed after 30 days of incubation and results were recorded. Plants irrigated with water had a root length of 6.8 cm, while plants irrigated with ZnO NPs solution had a root length of 14.5 cm. The results of increasing root growth are shown in Figure 4.

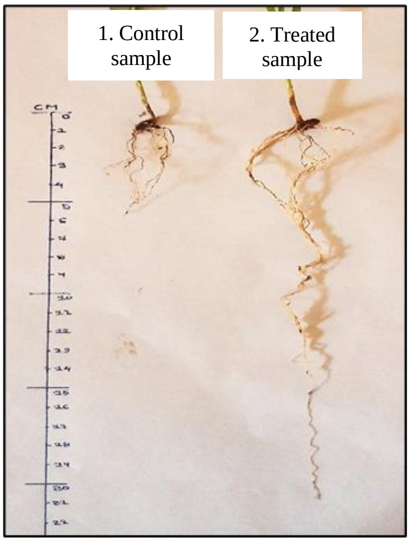

Figure 4. Effect of ZnO NPs on root growth of *Triticum aestivum* L.

The similar research was performed by [11], and a root length of 7.9 cm was recorded using ZnO NPs. The shoot length was measured in a time interval of 7 days, and the data are shown in Figure 5. The highest shoot length of 19.5 was recorded when plant was irrigated with ZnO NPs solution. In [12], the highest shoot length of 13.6 cm was recorded with the application of ZnO NPs in a concentration of 500 ppm, and the lowest of 6.1 cm was recorded with the control sample. A decrease in shoot length was observed with further increase in zinc concentration, with the exception in the case of ZnO NPs at a concentration of 1500 ppm [12].

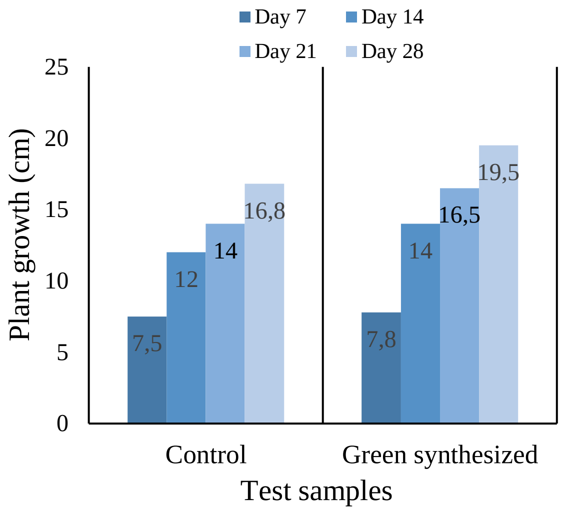

Figure 5. Effect of ZnO NPs on plant growth (*Triticum aestivum L.)*

CONCLUSION

The excessive use of traditional chemical fertilizers in agriculture negatively affects crop production and soil fertility, and since it depends on the fossil-fuel consumption, it contributes to the increase in greenhouse gas emissions and the harmful effects of climate changes. In this study, green synthesis of ZnO NPs was made using neem tree (*Azadirachta indica*) leaf extracts, and the characterisation was performed by UV-visible spectrophotometer and SEM analysis. During the study, green synthesized ZnO NPs used as nanofertilizers showed a positive effect on germination activity and growth of wheat (*Triticum aestivum L.*). Due to their small size, higher surface-to-volume ratio, and the existence of biological moieties, the bioactivity of green ZnO NPs is increased. This study concluded that the use of biological approaches in agriculture and crop production is a more applicable and more environmentally friendly tool than the use of chemicals.

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