RESEARCH ARTICLE

BIO-ASSISTED SYNTHESIS OF FERRIC SULPHIDE NANOPARTICLES FOR AGRICULTURAL APPLICATIONS

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ABSTRACT

Herein, Ferric sulphide nanoparticles were prepared by co-precipitation (green synthesis) method. Structural study (XRD) confirms the crystalline nature of prepared Ferric sulphide nanoparticles. The crystallite size was estimated and it was found to ~2.0 nm. The surface morphology of the Fe_2S_3 nanoparticles shows the agglomeration and is sponge and dried algae like structure. EDS analysis reveals the presence of Fe, S, O and C elements in the prepared Ferric sulphide nanoparticles. FTIR spectrum of Ferric sulphide shows the characteristic peaks that confirms the presence of Fe and S in the sample. Moreover, the plant growth study proves that Ferric sulphide nanoparticles could be used as a fertilizer to enhance the agricultural production.

Keywords: Green synthesis, Ferric sulphide, Agglomeration, Morphology

1. INTRODUCTION

The nanotechnology has got intensive applications for the enhancement of agricultural yield, along with the promising technologies for example biotechnology that including plant breeding, fertilizer technology, genetics and disease control. To overcome the challenges in sustainable production and food security, considerable scientific innovations have been made in the field of agricultural [1, 2]. Using the natural and synthetic resources, agricultural innovations are very essential to resolve the increasing food demand all around the global population.

Therefore, nanotechnology has a great impact to give very effective solutions to the several agricultural associated issues and a significant research has been carried out to highlight its important applications in agriculture region in the recent times [3, 4]. In addition to that, nanoparticles can provide a huge scientific curiosity in comparison to that of bulk materials. Though fertilizers have the important role to enhancement of the agricultural production, the excess usage proved to be change in the chemical ecology of soil and reduction in the existing area for crop production. So that, sustainable agricultural involves a minimum use of agrochemicals which can ultimately protect the environment. In particular, nanomaterials improve the crops production by increasing the effectiveness of agricultural inputs to produce the controlled delivery of nutrients. Furthermore, the main concern in agricultural production is to ensure the adaptation of plants with climate change issues like water deficiency, salinity, excessive temperatures and environmental pollution [5].

Moreover, agricultural land can be one of the main areas of concern for the discharged metal based nanoparticles (NP_s). To observe the effect of metal based NP_s in the field of agriculture ecosystem, it is very necessary to evaluate their revolution in agricultural environment. Plants are the major part in agriculture practice which has active interactions with metal based NP_s and many reviews have been reported on the stability and aggregation of NP_s in environment [6].

Considering the above facts, Iron (Fe) is an important nutrient for all organisms [7]. Iron deficiency is a rising issue with many different crops all over the world. Generally, Fe content in soil is extremely high, but a high percentage is fixed to soil particles [8,9]. Further, Fe is mostly in the form of insoluble Fe^{3+}, particularly in high pH and aerobic soils. So that, these soils are typically deficient in the existing form Fe^{3+} that lead Fe-deficient in plants where Fe participates in several physiological processes that including respiration, chlorophyll biosynthesis and redox reactions [8, 10]. Though, Fe deficiency not only affects the growth or expansion of plants, Fe deficiency results anemia in animals and human as well [11]. Therefore, it is very essential to enhance the utilization efficiency of Fe fertilizers. The purpose to use the Fe fertilizer is still very unique method to enhance Fe deficiency that could lead to increase the crop yield and rise the quantity as well. Fe_2O_3 nanoparticles have been

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utilized in the research filed of catalysis, biomedicine, water treatment and other fields. Not much work is reported on Fe_2O_3 nanoparticles used as fertilizer for agricultural production, especially Ferric Sulphide (Fe_2S_3). Therefore, the applications of Fe2S3 as a fertilizer still an important focus for many researchers. Here, a new type of fertilizer (Fe_2S_3) has been used to enhance the growth of cowpea plant, which can overcome such Fe deficiency in traditional fertilizer.

2. MATERIALS AND METHODS

2.1 Synthesis procedure to prepare Ferric sulphide nanoparticles using plant extract:

In the present work, the green synthesis of Ferric sulphide nanoparticles was prepared by Co-Precipitation method. Fe_2S_3 nanoparticles were synthesized via green synthesis by adding Ferric Chloride, Na_2S, to the solution of plant extract J*usticia-adhatoda*. Primarily, 5 ml of plant extract is added to 20 ml de-ionized water and stirred for 15 minutes using magnetic stirrer. Then, 6.48g of Ferric chloride is mixed in 40 ml of de ionized water and it is added drop wise for 15 minutes to the extract solution. Finally Na_2S (1.56 g) is added drop wise to the same solution and constantly stirred for 1hour. The solution is centrifuged and dried in an oven over 1 hr. The dried powder is crushed well into nano sized particles and the final product is calcination at 600°C for 4 hours to get fine ferric sulphide nanopowder. The structural, morphological, composition of the prepared nanoparticles was characterized using X-ray diffraction (XRD), Field emission scanning electron microscopy (FESEM), and Fourier transform infrared spectrum analysis (FTIR). Further, the application of prepared sample was studied by applying it with water and analyzes its role as the plant growth promoter.

3. RESULTS AND DISCUSSION

3.1 Structural analysis

The structural properties of Ferric sulphide nanoparticles were examined using XRD analysis. The sharp dominant diffraction peaks at 2θ = 33.22°, 37.22°, 40.55° and 54.75° corresponding to the (101), (111), (200) and (130) orientation planes confirms the orthorhombic crystalline nature of the prepared nanoparticles as shown in Fig.1.

The observed results are consistent with the standard JCPDS card no (03-065-2567). The crystallite size of the Fe_2S_3 nanoparticles was estimated using Scherer's formula and the estimated average crystallite size was found to be 2.0 nm. Moreover, the observed peaks confirm the polycrystalline nature of the Fe_2S_3 nanoparticles.
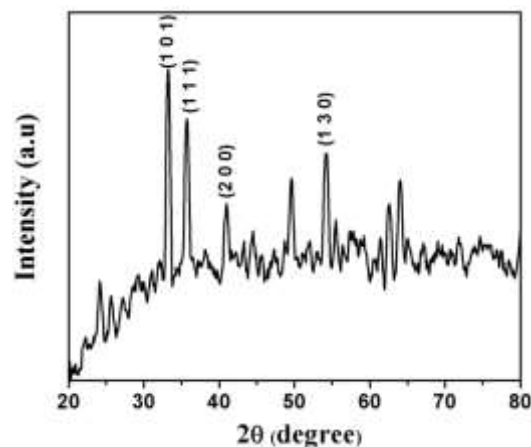
Fig. 1. XRD pattern of prepared Fe₂S₃ nanoparticles.

3.2. Field Emission Scanning Electron Microscope (FESEM)

The prepared Ferric sulphide nanoparticles were analyzed using FESEM (Quanta-200F) to know the surface morphology of the sample. Fig.2 shows the very clear surface morphology that signifies nanoparticles are well agglomerated and the surface appears to be spongy dried algae and sphere shaped.
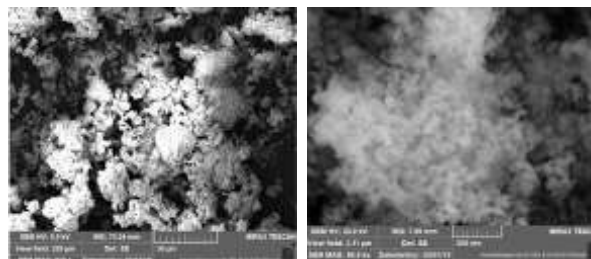
Fig. 2. FESEM images of prepared Fe₂S₃ nanoparticles in different magnifications

3.3 Elemental compositional analysis

The elemental composition of the prepared nanoparticles was carried out by Energy dispersive X-ray spectroscopy (EDS) to confirm the elements present in the system. It is evident from the peaks that the sample is composed of C, O, Fe and S elements. It also reveals the absence of any impurities in the prepared nanoparticles (Fig. 3).

3.4 Fourier Transform Infrared Spectroscopy

The FTIR spectrum of the prepared Ferric sulphide nanoparticles was performed using a

Thermo Scientific instrument, Nicolet 10 using a KBr pellet technique. Fig.4. represents the FTIR spectrum of ferric sulphide nanoparticles and it shows the characteristic peaks at 3136.25 cm-1 is due to the = C-H stretch i.e alkynes. Additionally, the peak at 1627.92 cm-1 confirms the presence of amide or amine. Further, the noticeable peak at 1402.25 cm-1 corresponds to O-H bond, peak at 1128.38 cm-1 corresponds to the alcohols (C-O stretch) compounds.
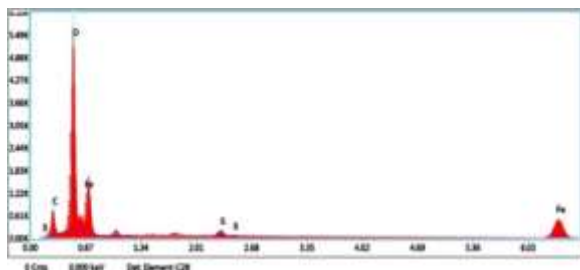
Fig. 3. EDS spectrum of Ferric Sulphide nanoparticles
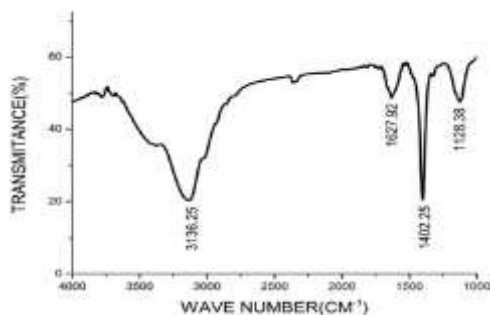
Fig. 4. FTIR spectrum of Ferric sulphide nanoparticles

3.5 Application of Ferric Sulphide nanoparticles in plant growth

Nanotechnology revolutionizes a new intensive technique in agriculture field by enhancing the capability of plants to absorb nutrients. Here, an attempt has been made to perform the application of the prepared Ferric sulphide nanoparticle as plant growth promoter.

After 7 days of observation, a very significant plant growth is observed in the nanoparticle applied sample compared to that of reference sample. The shoot length, root length, leaf and weight are well studied for both the samples. The results are proved that the sample with nanoparticle applied has notable increase in all parameters in comparison to that of the reference sample.

From the Table.1, it is very evident that the shoot length, root length, leaf length and number of leaves are low values for the reference sample (Fig. 5a) in comparison with the nanoparticle treated samples. Moreover, the observed seed growth is more in nanoparticle treated samples (Fig. 5b) which eventually lead to utilize such a kind of fertilizer for better enhancement in agricultural production.

Table.1 Effect of nanoparticles in plant growth

Objectives	Plant grown in pure water	Plant grown using NPs
Length of the shoot	1.3 cm	5 cm
Length of the root	2.7 cm	4.5 cm
Length of leaves	1 cm	3.5 cm
Number of leaves	2 No's	7 No's
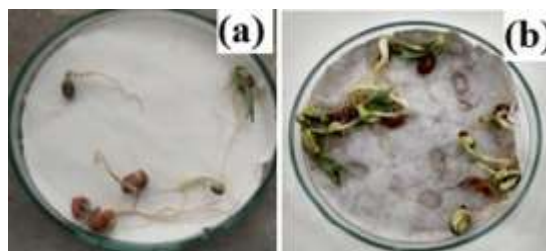
Fig. 5. Seed growth of cowpea plant (a) the reference sample (b) nanoparticle treated samples

4. CONCLUSION

Ferric sulphide nanoparticles were prepared by very simple co-precipitation method. Structural studies reveal Ferric sulphide nanoparticles are in polycrystalline nature. The estimated average crystalline size was found to ~2.0 nm. The surface morphology of the Fe2S3 nanoparticles shows the agglomerations of nanoparticles and are in sponge and dried algae like structure. EDS analysis confirms the presence of Fe, S, O and C elements in the prepared Ferric sulphide nanoparticles. FTIR spectrum shows the presence of Fe and S characteristic peaks in the sample. It is concluded that, the plant growth study proves Ferric

sulphide nanoparticles could be sed as a fertilizer to enhance the agricultural production.

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