Organised by : Universiti Teknologi MARA · RICAEN Research Industry Community Alumni Entrepreneurship Network

Programme by : INSPIRED 2024 Ipoh International Summit on Professionalism, Research & Education

In Collaboration With : BITCOM Business Innovation & Technology Commercialization Centre · MRM Majlis Rekabentuk Malaysia · MDEC

13TH INDES 2024

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THE 13TH INTERNATIONAL INNOVATION, INVENTION & DESIGN COMPETITION 2024

EXTENDED ABSTRACTS e-BOOK

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Office Of Research, Industry,
Community & Alumni Network
UiTM Perak Branch

Perpustakaan Negara Malaysia Cataloguing in Publication Data

No e- ISBN: 978-967-2776-31-4

Cover Design: Dr. Mohd Khairulnizam Ramlie
Typesetting : Zarinatun Ilyani Abdul Rahman

IRON OXIDE NANO-FERTILISER ENHANCING CHILLI GROWTH

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ABSTRACT

Iron oxide nanoparticles (Fe_3O_4-NPs) were synthesised using a mixture of rabbit urine and golden apple snails, using a greener approach. TEM analysis shows that the green synthesis Fe_3O_4-NPs were well agglomerated; the average particle size of Fe_3O_4-NPs was found to be 12 nm. The aim of this study is to assess their use as potential nanourine (NU) fertilisers for chilli plants' growth. There are five treatments: negative control, Fe_3O_4-NPs alone without urine (80%), Fe_3O_4-NPs combination with urine (25% NU, 50% NU, and 100% NU) were experimented on the grouped plants. It was found that 25% NU treatment is the optimum concentration to enhance chilli plant growth, giving the highest growth rate in plant leaves and stems. This formulated nano-urine fertiliser from rabbit urine might contain components that play a crucial role in promoting plant growth as it may be included with important nutrients, such as nitrogen, phosphate and potassium. The nanosize of this NU observed might cause better penetration into plant cells, ensuring efficient utilisation of the nutrients. This leads to improved crop yields and overall plant health, making it an eco-friendly and sustainable solution for agriculture.

Keyword: iron oxide nanoparticles, nanofertilizers, chilli, green synthesis, plant growth

1. INTRODUCTION

Chilli, scientifically referred to as *Capsicum annuum var. annuum L.*, is a significant vegetable in Malaysia. The plant is a member of the Solanaceae family and has its origins in the tropical and subtropical regions of the Americas (Swamy, 2023). Furthermore, it is utilised as an organic colouring and flavouring agent in the food sector. The ripe green chilli peppers are an excellent source of vitamins A and C, with 292 IU /100 g and 67 mg / 100 g, respectively. This is due to the presence of several carotenoids, including chlorophyll, provitamin A, carotene, and oxygenated carotenoids such as capsanthin and cryptocapsin (Saleh et al., 2018).

The need for sustainable agriculture practices that yield high output and ensure food security is more pressing than ever. Global food production and distribution systems are grappling with the effects of climate change, a burgeoning human population, shrinking fertile land, and dwindling freshwater supplies. These challenges necessitate the adoption of technical breakthroughs and significant changes to the current food production systems (Viana et al., 2022).

Conventional fertilisers cause environmental degradation, nutrient inefficiency, and deteriorating soil quality. They lead to reduced efficiency in nutrient utilisation, resulting in substantial financial losses and diminished soil fertility (Bindraban et al., 2020).

The utilisation of nanofertilizers has the potential to mitigate nutrient loss from fertilisers and potentially decrease fertiliser application rates. From this standpoint, it can be observed that nutrient losses, specifically of nitrogen and phosphorus, are reduced when they are packaged in nano form, as opposed to conventional forms. Therefore, nanotechnology has the potential to mitigate the environmental impacts caused by traditional fertilisers (Yadav et al., 2023).

Nanotechnology, through the development of nanofertilizers, has emerged as a potential solution to these challenges. It plays a crucial role in crop production, meeting the growing food demands of the population while ensuring environmental integrity, sustainability, and economic stability. The unique chemical composition of nanofertilizers can enhance nutrient uptake, restore soil fertility, improve absorption rates, boost photosynthesis, increase crop yields, reduce soil toxicity, minimise the need for frequent application, enhance plant health, and reduce environmental contamination. The use of nanofertilizers that leverage the unique properties of nanoparticles could significantly enhance the efficiency of nutrient utilisation (Saritha et al., 2022).

Nano-fertilisers have a larger surface area than commercial chemical fertilisers. This helps plants absorb nutrients better, resulting in more efficient fertiliser usage and economic benefits. They also improve soil characteristics and increase its ability to retain water and fertiliser (Babu et al., 2022).

This research aims to optimise the use of readily available waste products, namely rabbit urine and discarded snail shells, by utilising them as reducing agents for making nanofertilizers. In addition, these nanofertilizers can deliver nutrients to plants in a controlled and continuous manner, hence enhancing the efficiency of nutrient utilisation.

2. METHODOLOGY

2.1 Green Synthesis Iron Oxide (Fe_3O_4) Nanoparticles

The liquid organic fertiliser, LOF (mixture of rabbit urine and golden apple snail) was obtained from the Faculty of Science and Technology, Universitas Darussalam Gontor (UNIDA). Iron oxide nanoparticles were produced using a one-pot-two-step co-precipitation method, with LOF as the eco-friendly reducing agent. Briefly, 0.40 g of iron (II) chloride tetrahydrate ($FeCl_2.4H_2O$) and 1.10 g of iron (III) chloride hexahydrate ($FeCl_3.6H_2O$) were dissolved in 100 mL of deionized water. The resulting mixture was heated to 80°C for 10 minutes until a homogeneous solution was obtained. Then, 10 mL of rabbit urine was slowly added to the hot mixture. 20 mL of ammonium hydroxide was added to the reaction mixture drop by drop with vigorous stirring for 30 minutes. Upon the formation of Fe_3O_4-NPs, an instantaneous black colour appearance was observed. The mixture was then allowed to cool down to room temperature for 30 minutes. The intense black precipitate Fe_3O_4-NPs was washed with deionized water and centrifuged at 5000 rpm for 10 minutes to remove residual salts. The above procedure was performed three times before further application.

2.2 Characterization

The size and the morphology of the Fe_3O_4-NPs were investigated by transmission electron microscopy (TEM) using Talos L120C (Thermo Fisher, USA) working at 120 kV. The samples were prepared by drop deposition of a diluted solution onto a carbon-coated 200 mesh grid. The grid was air-dried for a few hours before the TEM studies.

2.3 Treatment of chilli plants

Different concentrations of Fe_3O_4-NPs were applied as fertiliser treatment at 25, 50, and 100% NU together with 80% of nanoparticle (NP) and distilled water (negative control). The nano-fertiliser treatments were then distributed by foliar application onto all of the chilli leaves until they were dripping wet equally. The growth performance of sprayed plants was evaluated by measuring the growth rate in plant length and leaf length over a specific time period calculated using the formula provided below:

$$\textit{Growth Rate} = \textit{Initial Length}\ (\textit{Final Length} - \textit{Initial Length}) \times 100\% \tag{1}$$

3. FINDINGS

3.1 Transmission Electron Microscopy (TEM)

The images in Figure 1 indicate that Fe_3O_4-NPs are mostly irregular in shape, with an average particle size of 12 nm. The nanoparticles formed agglomerations and adhered to each other, leading to the creation of particle aggregates and irregular arrangements. The TEM analysis confirms that the nano-fertilisers fall within the nanometer-scale size range.

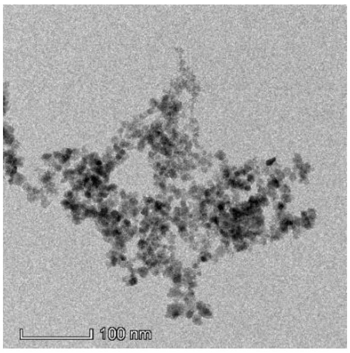

Figure 1 TEM image of iron oxide nanoparticles.

3.2 Plant growth

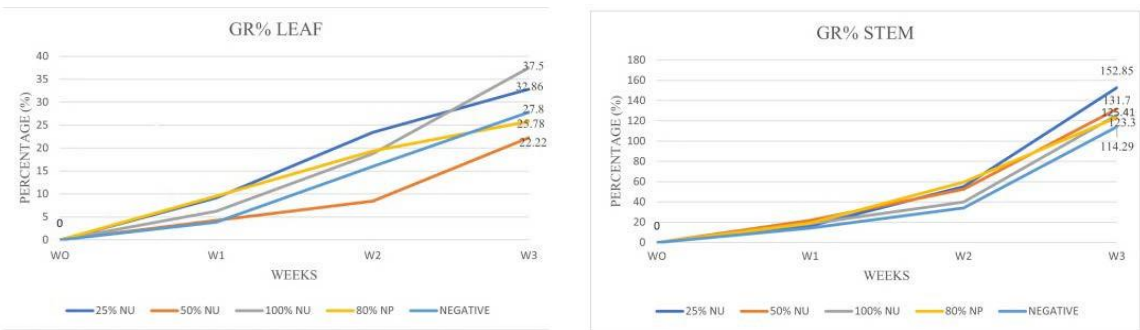

Figure 2 Growth Rate Percentage of Chilli Plants' Leaf and Stem

Considering the graphs of Figures 1 and 2, it is evident that chilli plants subjected to a 25% NU concentration exhibit the healthiest growth trajectory. This specific concentration fosters not only a larger percentage of growth on leaves (32.86%) but also stems (152.85%), highlighting its potential to promote the overall robustness and vitality of *Capsicum annum*. The larger leaves observed in nanourine-treated plants suggest improved photosynthetic capacity and nutrient assimilation, contributing to enhanced plant health and productivity. Additionally, the taller stems signify increased stem elongation, which can lead to better structural support for the plant and improved access to sunlight for photosynthesis. The positive growth response to the 25% NU concentration underscores its role as a growth promoter. The nanoparticles in nanofertilizers have a significantly higher surface area compared to conventional fertilisers. This increased surface area allows for better interaction with plant roots and soil, leading to improved nutrient uptake efficiency. Nano-urine fertilisers can penetrate plant tissues more effectively, allowing for better absorption of nutrients. This can lead to improved overall plant health, vigour, and growth rates.

4. CONCLUSION

In this present study, it is reported that the successful use of a mixture of rabbit urine and golden apple snail as a one-pot green method for the synthesis of Fe_3O_4-NPs. The instantaneous black colour change suggested the formation of iron oxide nanoparticles. The rapid reduction process proved the efficiency of rabbit urine extract as a reducing and stabilising agent. TEM showed the formation of Fe_3O_4, with an average size of 12 nm and an irregular shape. For the chilli plant growth effect, the formulated 25% nano-urine fertiliser has been shown to give great benefit. This concentration led to significantly larger leaves and taller stems, indicating better nutrient absorption and structural support. The nanourine's nanoparticles boost nutrient uptake efficiency, contributing to healthier and more vigorous plants. Exploring these findings further could lead to improved agricultural methods and higher crop yields.

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