

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(4): 261-264
www.biochemjournal.com
Received: 20-01-2025
Accepted: 25-02-2025

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Synthesis and characterization of potassium nanofertilizer from vermiwash

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DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i4d.4099>

Abstract

A study was carried out to synthesize and characterize potassium nanofertilizer in an eco-friendly way from byproduct of vermicompost i.e. Vermiwash. Nutrient analysis of the synthesized nanofertilizer showed that the amount of macronutrients like N, P, K, Ca, Mg and Na were increased by 1.04%, 0.95%, 0.98%, 0.04%, 0.06% and 0.02%, respectively. The micronutrients like Fe and B were increased by 3.85 ppm and 0.03 ppm, respectively. The amount of Cu, Zn, and Mn were increased by 0.02 ppm. The organic compounds, like carbohydrate, crude fat, crude protein, tryptophan and ash content were 0.34%, 0.03%, 2.98%, 0.05% and 0.01%, respectively. The average size of K nanoparticles in Vermiwash was found to be 34.6 nm with 100 % intensity through Dynamic Light Scattering technique (DLS). Transmission Electron Microscopy (TEM) images of Vermiwash extract contributed to the findings showing nanospherical structure, of size range from 20 to 28 nm. On application of synthesized K nanofertilizer (20 ml/lit) in Toria crop, the germination rate increased from 26.2 % in control (without nanofertilizer) to 96.4 % after 7 days of plantation.

Keywords: K nanofertilizer, Vermiwash, TEM, DLS, zeta potential

Introduction

Nanofertilizers are the fertilizers having particle size of less than 100 nm. Its smaller sizes makes it possible to entry into the plant system through hydathode, stomata and cell wall of the plant. Nanofertilizers application can supply nutrients to the plants in a gradual and controlled manner. They also have the ability to minimize nutrient losses through leaching, volatilization, and avoiding rapid changes in their chemical nature (Raliya *et al.*, 2017) [16]. Nanoparticles can hold a lot of nutrients because of their large surface area and release it gradually so that the crop can absorb the nutrients it needs without experiencing any negative side effects from the specific fertilizer applications (Gupta *et al.*, 2020) [9]. There is extremely little literature on nano-fertilizer technology, despite the fact that it is a very novel technology. Although numerous disciplines fall under the umbrella of agriculture, the speed of progress is moderate, despite the fact that nanotechnology in agriculture has accelerated over the past ten years with a plethora of public financing (De Rosa *et al.*, 2010) [6]. Therefore, it contributes to boosting crop output, reducing fertilizer waste, and safeguarding the environment by enhancing the bioavailability and uptake of minerals (Tapan *et al.*, 2010, Tarafdar *et al.*, 2014, Dimkpa Bindraban, 2016) [20, 21, 7]. For high crop yields and soil regeneration, nanofertilizers (NFs) have emerged as a possible smart fertilizer substitute. To feed the huge world population, there will be more pressure on the resources like land and water which are not extendable. The increasing population caused the heavy use of fertilizer for supplying necessary nutritional food. The intensive use of chemical fertilizers has different possible side effects on the human and environment. After all various fertilizers focused on plant nutrition, the NFs found and studied as a way to boost nutrient dosage and plant nutrition along with healthy food, as compared with traditional fertilizers. NFs have gained the attention of agricultural engineers, environmentalists, and soil scientists due to their power to increase crop yields, positivity to soil fertility, trimming down pollution, and mark aurgeon Eco to flourish microorganisms.

In recent years K nanofertilizer was prepared from various plant extracts viz. banana peel (Hussein *et al.*, 2019, Franck *et al.*, 2020) [11, 8] *Morus alba* plant leaf extract (Sheoran *et al.*

2021)^[19] and through chemical synthesis Sebastian *et al.* (2024)^[18]. K nanofertilizer can also be prepared from Vermiwash which is a byproduct produced during vermicompost preparation. Vermiwash is considered as a liquid fertilizer due to the presence of macro nutrients, micronutrients and existence of humic acid and fulvic acid in it (Guteirezz Miceli *et al.*, 2008)^[10]. But releasing the vermiwash as such into the environment, especially if it is near ground water source will cause pollution (Katheem Kiasuddin *et al.*, 2016)^[14]. Transforming this organic product into a valuable resource like K nanofertilizer and its application in agriculture, will boost agricultural productivity, thereby satisfying the needs of growing population for food security. To the best of our knowledge synthesis of K nanofertilizer from vermiwash was the novel approach that we have initiated. With this viewpoint the present study was carried out with an objective to synthesize and characterize K nanofertilizer from vermiwash and to study its effect on germination percentage of Toria crop.

Materials and methods

Preparation of nanofertilizer from vermiwash

Vermiwash collected from vermicompost tanks existed at Krishi Vigyan Kendra, BARPETA was filtered through a funnel using filter paper to get rid of any particles. One hundred milliliters of vermiwash were combined with 400 milliliters of 0.1 M KCl. After 24 hours of heating the mixture to 70 °C, the precipitate was segregated by centrifugation for five minutes at 6,000 rpm. The nano particles were dried in an oven set at 80 °C after being five times cleaned with ethanol and double-distilled water (Arslan *et al.*, 2022)^[3] and were used for study of relevant properties.

Analysis of extract

The alkaline extract of the vermiwash was digested with concentrated nitric acid at elevated temperatures. The resulting solution was digested and the extract contents were used for determination of the N, P, K, Na, Ca and Mg contents by following the procedure described by Jackson (1973)^[12]. The levels of micronutrients such as iron, copper, zinc, boron and manganese were determined as described by Layne (1975)^[15]. The crude fat content, crude protein content, Tryptophan and ash content were analysed by using the standard methods described in Association of Official Analytical Chemists (AOAC 1995).

Characterization of synthesized fertilizer

The size distribution and zeta potential of the synthesized fertilizer were determined by DLS technique using the instrument Zetasizer version 7.13, Malvern. The physical

dimensions of the potassium nanoparticles were determined by TEM (JEM-2100 PLUS (HR), JEOL). This instrument is capable of high resolution EELS (Electron Energy Loss Spectroscopy) for analysis of the bonding state at the nanometer scale. The drop coating method was employed for sample preparation. A drop of suspension containing nanoparticles was placed on the carbon-coated copper grids and dried overnight under vacuum desiccators. The sample was placed on a specimen holder and characterized.

Nanofertilizer application in agriculture

Toria seeds (variety. TS 38) were sown under green house on 10/11/2024 and were fertilized with (5, 10, 15 and 20) ml/l of K nanofertilizer extracted from vermiwash. The germination rate was determined after one week. The soil used for the study was sandy loam with pH 6.3 and electrical conductivity 0.01 dS/m. Simple correlation test was done to measure the correlation between applied extracted fertilizer and germination rate of the crop.

Results and Discussions

The total N, P and K contents of K nanofertilizer extracted from Vermiwash (V) were 1.45%, 0.79% and 2.41%, respectively, while the contents of Ca, Mg and Na were 0.11%, 0.08% and 0.03%, respectively (Table 1). The micronutrient contents like Fe, Cu, Zn, B and Mn were found to be 15.2 ppm, 0.05 ppm, 0.08 ppm, 0.07 ppm and 0.04 ppm, respectively. The organic compound contents like carbohydrate, crude fat, crude protein, tryptophan and ash content were determined to be 1.2%, 0.07%, 15.31%, 0.09% and 0.08%, respectively (Table 1).

The percent increase of N, P, K, Ca, Mg and Na were 1.04%, 0.95%, 0.98%, 0.04%, 0.06% and 0.02%, respectively, whereas, the micronutrients like Fe and B contents were raised by 3.85 ppm and 0.03 ppm, respectively. On the other hand, the contents of Cu, Zn, and Mn were increased by 0.02 ppm. Similarly, the percent increase of carbohydrate, crude fat, crude protein, tryptophan and ash content were 0.34%, 0.03%, 2.98%, 0.05% and 0.01%, respectively.

Among the macronutrients, K content was found to be highest (2.42%) in the vermiwash extract. Use of K rich inputs like Banana stems during the production of vermiwash might increased the amount of K in the vermiwash extract. Higher amount of K content compared to nitrogen, phosphorus and other nutrients in Vermiwash were also observed by Carlos *et al.* (2008)^[4]. Cabilovski *et al.* (2023)^[5] reported that vermicompost leachate i.e Vermiwash consist of many nutrients that are beneficial to plant growth.

Table 1: Total macronutrient, micronutrient and organic compound content in vermiwash extract.

	Macronutrient					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)
Initial	1.42	0.51	1.44	0.11	0.03	0.02
Final	2.46	1.46	2.42	0.15	0.09	0.04
	Micronutrient					
	Fe (ppm)	Cu (ppm)	Zn (ppm)	B (ppm)	Mn (ppm)	-
Initial	11.35	0.03	0.06	0.04	0.02	
Final	15.2	0.05	0.08	0.07	0.04	-
	Organic compound					
	Carbohydrate (%)	Crude fat (%)	Crude protein (%)	Tryptophan (%)	Ash content (%)	-
Initial	0.86	0.04	12.33	0.04	0.07	
Final	1.2	0.07	15.31	0.09	0.08	-

Zeta sizer

The size distribution by intensity report through Zeta sizer gives a vivid picture about the average size of the K nanoparticles present and intensity of nano size particles in the synthesized nanofertilizers. The average size of K nanoparticles in Vermiwash determined by the instrument Zeta Sizer, was found to be 34.6 nm with 100 % intensity and Poly dispersity index (PDI) value 0.381 (Fig.1), showing a high degree of particle monodispersity (Sheoran

et al. 2021) [19]. The zeta potential of the extracted fertilizer was observed to be high (-31.9 mV) because of its smaller size. The high zeta potential of the particles prevents aggregation, resulting in a stable solution (Sheoran *et al.* 2021) [19]. It was seen from the above findings, in general, that the techniques used for synthesis of nano-fertilizers were adequate and successful. The results of Hussein *et al.* (2019) [11] were also found to be in line in the present study.

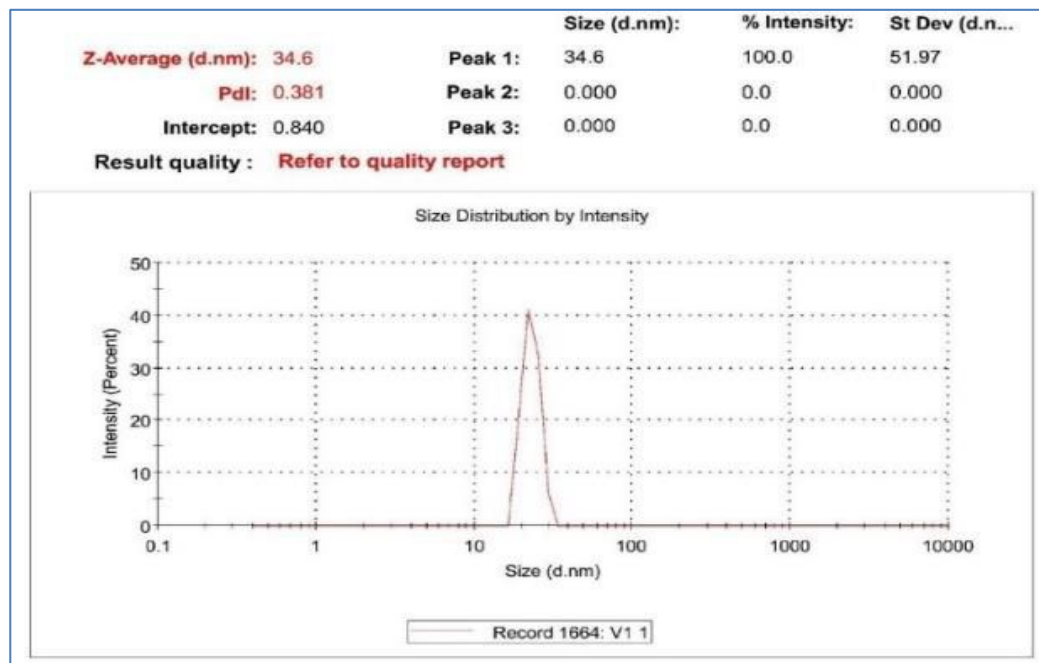


Fig 1: Size distribution of nanoparticle as showed by Zeta Sizer

Transmission Electron Microscopy (TEM)

The TEM analysis of the obtained vermiwash extract by using KCl as extracting agent shows that nanospherical structure particles were obtained with size range from 20 to 28 nm (Fig: 2). The presence of both citric acid and urea was responsible for the conversion to nanostructure because citric acid combines with minerals to generate mineral citrate, and urea was required to transport this mineral citrate in the nanoform. Similar type of findings were also observed by Hussein *et al.* (2019) [11] and Sheoran *et al.* (2021) [19].

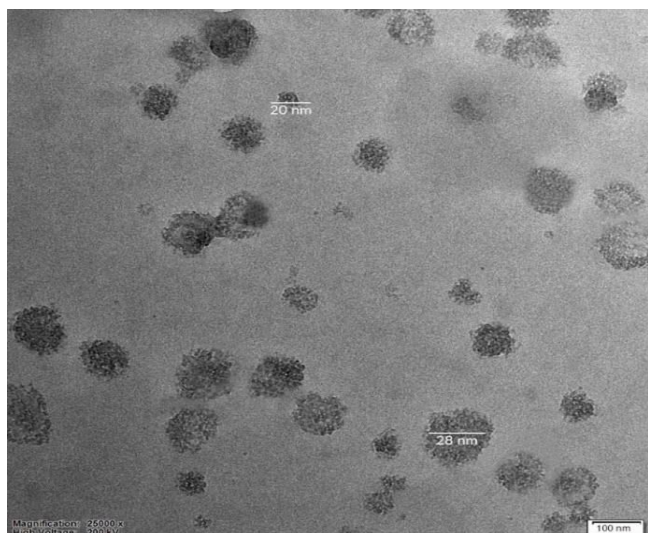


Fig 2: Size distribution of nanoparticles as described by TEM

Effect of applied nanofertilizer in Toria crop

Application of synthesized nanofertilizer from vermiwash had a significant positive correlation with germination percentage of Toria crop. The statistical analysis for Pearson correlation gives r^2 value 0.97. This significant and positive result of the germination test might be due to the characteristics of nanofertilizers which have the ability to entry into the plant system through the minute pores because of its smaller size. The germination percentage of Toria increased with increased in dose of K nanofertilizer applied and the highest was obtained with 20 ml/l of K nanofertilizer. Presence of other organic compounds like tryptophan, amino acids and other essential nutrients present in the nanofertilizer might also have boost the germination process. Tryptophan plays an important role during plants growth (Sadak and Orabi 2015; J Lv *et al.* 2019) [17, 13]. In addition metal ions present in the nanofertilizer mix with organic components to create chelates which makes the plant resistance to precipitation loss (Aboul-Enein *et al.* 2016) [1].

Table 2: Effect of K nanofertilizer on germination percentage of Toria crop

Quantity of K nanofertilizer applied (ml/l)	Germination (%)
0	26.2
5	40.4
10	75.2
15	86.1
20	96.4

Summary and Conclusion

Vermiwash extract can be successfully converted into a valuable K nanofertilizer under alkaline condition. Average size of the nanoparticles showed through Zeta sizer was 34.6 nm. TEM images confirmed the findings by showing minimum size of the nanoparticles being 20 nm. In this investigation, the extracts of vermiwash contained 4.42% elemental potassium. A positive and linear relationship was observed with the rate of vermiwash application and germination percentage of Toria. Application of 20 ml/l K nanofertilizer increased the germination rate by 70.20%. Thus, it can be concluded that application of eco-friendly synthesized K nanofertilizer from agricultural byproducts will improve the growth and development of crops by improving its fertilizer use efficiency in a sustainable way.

Future prospects

The present study was based on laboratory experiments. Multi location field trials with different doses of K nanofertilizer prepared from vermiwash is required for recommendation.

Acknowledgement

The authors thank Sophisticated Analytical Instrumentation Centre (SAIC), Institute of Advanced Study in Science and Technology (IASST), Guwahati (under the Department of Science & Technology, Government of India) for TEM analysis.

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