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Preparation of organic nano-fertilizers as a growth boosting agent for mustard and lettuce

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Abstract

In Hakha of Chin state, Myanmar, mustard and lettuce are basically grown in every part of the town irrespective of the season for both at-home and out-of-home consumers. The fertilizers used by growers are mostly conventional. They do not use any fertilizers which are scientifically prepared. In this study, organic nano-fertilizers (ONFs) were systematically prepared from cow manure combined with carbon nanoparticles produced from banana peels extracts. This research was aimed to analyze physicochemical properties and to evaluate the effect of fertilization efficiency of the prepared ONFs on mustard and lettuce. They were characterized using analytical techniques such as UV-vis, FTIR, XRD, EDXRF, SEM and AAS. And the application of ONFs in agriculture was studied. As a result, prepared ONFs were found to be 430 nm of UV-vis peak, 64 nm in diameter, potential functional groups, high content of potassium and iron fertilizer, amorphous nature and homogeneity with stable coating structures of microscopic deformations. The NPK fertilizers demonstrated a balanced ratio of 34:1:70 ppm in ONFs, however; phosphorus was found in very small amounts. Most importantly, the growth percentage of mustard and lettuce with applying ONFs was found to be 97.7% and 93%, respectively. To sum up, it is hoped that these organic nanofertilizers could be used effectively as a growth promoting agent of mustard and lettuce in vegetable crops agriculture according to the explored results and findings.

Keywords: banana peels, cow manure, carbon nanoparticles, nanofertilizers

Introduction

Organic fertilizers can be found naturally in mineral sources, containing moderate amounts of essential plant nutrients. They are relatively efficient in reducing unwanted problems associated with synthetic fertilizers (Shaji et al., 2021). They do not need to be used repeatedly like synthetic fertilizers to maintain soil fertility. Their nutrients are released into the soil to maintain nutrient balance for healthy plant growth. They also serve as an important energy source for soil microbes which, in turn, enhances soil texture and plant growth. (Verma et al., 2020). Organic fertilizers are considered to be safer fertilizers than synthetic fertilizers. They are slow-release and contain many trace elements. However, inappropriate use of organic fertilizer causes excessive fertilization or lack of nutrients in the soil (Bamdad et al., 2022).

Organic fertilizers consist of various plant-originated materials, ranging from fresh or dried plant material to animal feces and litters to agricultural by-products. Depending on the different starting materials, the nutrient composition in organic fertilizers is very different, and better sources of nutrients are widely available from biodegradable materials (Barłóg et al., 2022). The content of nitrogen and phosphorus is lower to a great extent in organic fertilizers in contrast with chemical fertilizers. Moisture content affects the reduction or dilution of nitrogen and phosphorus concentrations of organic fertilizers (Sankar Ganesh et al., 2017).

Therefore, if high moisture content of organic fertilizers is transported over long distances, it becomes less effective. However, it is applicable if their use is in conformity with the production methods (Rashmi et al., 2020). The nutrient value is not having a fixed ratio in animal manures in contrast to that of agriculturally ready-made fertilizers. Manure nutrient content is much affected by factors such as animal's food, bedding material, manure lifetime, and the place where it was stored; among farms, these factors are variable depending on region and geographic scale (Das and Avasthe, 2018). On the other hand, nutrient value is found less variable in agricultural by-products in accordance with the industrial process of production (Das and Avasthe, 2018).

Recently, organic fertilizer has drawn great attention to agricultural scientists since the use of organic waste is growing fast as fertilizers. Organic fertilizers can be readily generated from plant-based wastes using composable organic matter wastes, which, in turn, can be used for soil fertility. For instance, one of organic wastes, banana peel, has gained special attention due to its noticeable components such as vitamins, flavonoids, essential amino acids, growth promoters, and potassium element. They play a key role in plant growth (Hussein et al., 2019). Moreover, banana peel has played in a very important aspect in plant cultivation, increasing seed germination rate due to high contents of potassium, amino acids (i.e., L-tryptophan), and other growth promoters (Naksing, 2020).

Furthermore, carbon nanoparticles are also providing the agriculture sector acting as nanocarriers due to its friendly environment and high surface-to-volume ratio. They can induce water and nutrients for months or years, releasing steadily as much as the plant required. So, this characteristic makes them smart nanofertilizers (Supriya et al., 2020). Many advantages have been found in nanofertilizers for the reduction of synthetic fertilizers through their target-specific strategy. They are capable of supporting nutrition to the cell, which protects the unwanted release of chemicals in human society. Soil and water pollution of synthetic chemicals can be reduced by application of nanofertilizers, which are known as sustainable fertilizer agents. Therefore, different kinds of carbon-based nanomaterials have been researched as fertilizers towards different crops (Avila-Quezada et al., 2022).

Carbon-based nanomaterials have a high resistance to stress of plants. A study confirmed that fullerenol exhibited the ability to alleviate drought stress. It was explored that fullerenol entered the root and plant leaves with a certain water supply (Shekhawat et al., 2021). Similarly, it was also found that the toxic effect of salt stress in sorghum and switchgrass was significantly decreased by prepared carbon nanoparticles. They also found that the carbon nanoparticles could enhance stages of the seed germination and young seedlings. Moreover, carbon-based nanomaterial helps in suppressing the salt stress condition due to the stress tolerance proteins in sorghum. In particular, water-soluble carbon nanomaterials are more useful in enhancing plant growth in contrast with nonfunctionalized carbon nanomaterials (Rezaei Cherati et al., 2021).

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Moreover, ONFs are fertilizers that combine organic matter with nanoparticles to improve nutrient delivery and soil health. For example, they were designed from nano-humic acid fertilizers combined humic acid with nanoparticles to increase nutrient uptake and enhance soil microbial performance. They are one of green nanoparticles which originated from raw organic wastes (Soman and Balachandran, 2021). It was then prepared as nutrients supplied to the soil. They are green and environmentally friendly, which are produced from natural products. They are capable of maintaining adjustable pH levels and soil moisture, supplying plants to receive essential nutrients. Organic nanoparticles can be prepared from smaller atoms or molecules to obtain largely different capsules, polymer conjugates, vesicles, micelles, liposomes, polymersomes, dendrimers, and polymeric nanoparticles. The common natural polymers for the preparation of nanofertilizers are various gums and seeds (Soman and Balachandran, 2021).

Furthermore, ONFs can provide more efficiently in growing plants due to its slow release of nutrients to soil, which leads to better growth and increased yields. Soil fertility and structure can be improved properly by applying ONFs, increasing aggregation and porosity, enhancing water infiltration, aeration, and root penetration (Lehmann and Kleber, 2015). Moreover, organic matters act as a key of nutrients carrier for soil microorganisms, stimulating their growth and features (Masciandaro et al., 2013). In this regard, nutrient release and availability were certainly contributed to the plant's cultivation area, which further improve soil fertility and plant growth (Prasad et al., 2021). ONFs are commonly preparable from organic wastes such as plant waste, manure, and compost. For instance, NanoMax-NPK, one of nanofertilizers, is commercially available in the real market for all crops. It was designed with various organic micronutrients such as vitamins, probiotics, and organic acids (protein-lacto-gluconates) containing chelated N, P, K, O, amino acids, and organic carbon (Fatima et al., 2021).

Organic nanofertilizers derived from combining organic materials with ONFs gained unique properties including abiotic stress tolerance, high sorption capacity, amplified surface-to-volume ratio and controlled-release kinetics to directed sites (Kamaly et al., 2016). Thus, they help them give fast growth of plant in soil. These distinguishing features make it become a plant's smart delivery system of nutrients. In contrast with other common fertilizers, ONFs support delayed nutrient release, which improves nutritional management, such as reducing nutrient leaching and amplifying nutrient-use efficiency (Iqbal and Mahmooduzzafar, 2019).

Chin State is situated in the western part of Myanmar, bordering with Sagaing Region in the east, India in the west, Kachin State in the north and Rakhine State in the south. The main livelihood of the rural community of Chin State is shifting cultivation. The limited area of arable farmland on the steep hilly areas and growing population of the State shorten the shifting cultivation fallow period and lead to poor soil fertility. In addition, deforestation, climate change and irregular rainfall across the State have a negative impact on food production. In Hakha of Chin state, Myanmar, rapid climate change like drought stress in winter is a main problem, which results in significant reduction in the yield potential of major vegetables and crops. Thus, the above-mentioned occurrences greatly motivated us to do the research.

In this research, banana peels extracted-carbon nanoparticles and cow manure extracted liquids were mixed together to enhance soil fertility. Bananas (*Musa acuminata*) are grown all over the world and consumed as ripe fruit or used for culinary purpose. All parts of the banana plants have medicinal applications. This research mainly aims to support mustard and lettuce growers in Hakha. The formulated ONFs were subjected to characterize physical and chemical properties using important analytical techniques such as UV-vis, FT-IR, XRD, EDXRF and AAS. In particular, the prepared ONFs were applied as fertilizer towards mustard and lettuce irrigation, and it was noticed that the growth percentage of mustard and lettuce was increased to 97% and 92%, respectively, when applying the optimum dose of 25g/ L of ONFs in contrast to the standard zero applied ONFs. Therefore, it is anticipated that these ONFs could be used effectively as a growth promoting agent of mustard and lettuce in vegetable crops agriculture according to the explored results and findings.

The aim of this research is to prepare organic nanofertilizers (ONFs) and to assess the effect of ONFs on the plant growth percentage of mustard and lettuce. The objectives of this research were: to prepare organic nanofertilizers (ONFs); study the maximum absorbance peak of prepared ONFs; identify the characteristic peaks of functional groups of produced ONFs; characterize the nature of phase of carbon nanoparticles; investigate the elemental contents of prepared ONFs; find out nitrogen content by kjeldahl method; identify heavy metals contents and to evaluate fertilization efficiency of prepared ONFs on the growth of mustard and lettuce. Research problems were: How to prepare ONFs successfully from combining cow manure with waste of banana peels extract? Is the used method effective and what analytical techniques were used for characterization of the prepared ONFs? How to evaluate the effect of fertilization efficiency of prepared ONFs on mustard and lettuce growth?

This research provided information that wastes of banana peels and cow manures were transformed into value-added products of organic nanofertilizers. In addition, the study used an easy and fast method effectively and also this research explored cost-effective ONFs for boosting mustard and lettuce growth.

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Materials and methods

Chemical and reagent

The materials used in this research were NaOH, concentrated HCl, ammonia, and KOH, which were purchased from Myanmar Chemical Mart (244/246 Konezaydan street, Yangon, 11141). All of the chemicals were analytical grade. Deionized water was used throughout the experiment.

Preparation of carbon nanoparticles

Firstly, the fresh banana peels (300 g) were washed well with tap water to remove the dust and impurities adhered to the outer surface. They were chopped into small pieces and grinded using domestic blender until viscous slurry was obtained. Then, the fresh slurry of banana peels was obtained. Those banana peels liquids were filtered using Whatman filter paper. The clear liquid was collected. Secondly, the clear liquid was placed on hotplate magnetic stirrer for 2 hr at 80 °C under vigorous stirring. Then, 20 mL of the ammonia solution was added into the mixture solution and stirred for 1 hr again. Finally, homogenous mixture was obtained and 250 mL of the homogeneous mixture was put into laboratory oven at 190 °C for 2 hr. Then, the temperature was cooled down. Solid black crystal particles were obtained. The process of filtration, separation and centrifugation were done to optimize carbon nanoparticles for further analysis (Hano and Abbasi, 2021).

Preparation of cow manure extract

The fresh and wet cow manure (1000 g) was collected in the clean pot. After that, it was to keep the air dry in the laboratory room for 3 weeks and grinded into very small pieces. Then, the powders of fine cow manures were boiled to obtain viscous slurry and 0.5 M of potassium hydroxide solution was added into the extracted cow manure with constant stirring under heating at 80 °C on hotplate. After the liquid of the cow manure solution was nearly getting dried, the temperature was cooled down. Dried particles were obtained for further use (Hano and Abbasi, 2021).

Preparation of organic nanofertilizers

ONFs were synthesized through the following procedure. To the reaction flask, 100 g/ L of carbon nanoparticles solution was added into 200 g/L of cow manure dried extract and continued reaction with stirring for 30 min. Then 100 mL of deionized water was added by means of drop wise. The reaction was further allowed to continue under stirring for 2 hr at 80 ℃ and centrifuged at 3000 rpm for 20 min to obtain homogeneous clean mixture solution. The pH of homogenous clean mixture was adjusted at 6.5. After that, the pure concentrated solution of ONFs was obtained and it was successively heated at 100 °C in oven until it was getting dried. Finally, the dried powder of ONFs was collected and kept in bottle for further characterization and application.

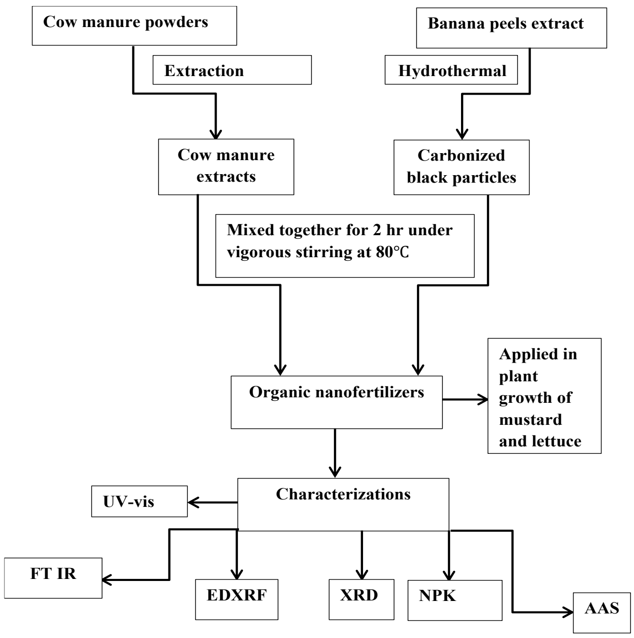

Figure 1. The schematic diagram of research flow chart.

Characterization of organic nanofertilizers

The present study described the synthetic process of ONFs. The prepared ONFs were further characterized by using UV-vis, FTIR, EDXRF, XRD, SEM and AAS analysis. Moreover, nitrogen contents in ONFs were done by kjeldahl method. Moreover, the absorbance peak of ONFs was carried out using UV-vis spectrophotometer of LAMBDA™ 265 (PerkinElmer). The FTIR analysis was used to identify the functional groups in ONFs using FTIR spectrophotometer (IRPrestige-21, Shimadzu, Japan) within the range of 400-4000 cm^{-1}. The elemental analysis of ONFs was determined by using EDXRF (Shimadzu EDX-700 Spectrometer). The XRD studies were used to give the information of nanosize of the prepared carbon nanoparticles using Rigaku Multijlex 2KW Powder X-ray, Akishima, Tokyo, Japan in the Universities' Research Centre of Yangon University (URC-YU). The morphology and structural distribution of ONFs were analyzed by SEM technique using FESEM, Zeiss Ultra60 in the Department of Chemistry, Yatanapon University, Myanmar. The elemental contents in ONFs were studied using atomic absorption spectrophotometer (Nov AA 400) technique.

Application of organic nanofertilizer in agriculture

Seeds of two vegetative crops (mustard and lettuce), 10 seeds of each crop, were used, and the seeds were cultivated in the collected soil from the research site at Hakha University, Chin state, Myanmar with its physical properties and composition of sand 25%, silt 37% and clay 38%. The seeds were irrigated in the taken soil and watered them twice a day under humid subtropical climate. And different concentrations (0, 5, 10, 15, and 25 g/L) of prepared ONFs solutions were applied on mustard and lettuce plants, respectively (Photo 1). Afterward, data concerning with growth

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percentages were recorded every 10 days for 2 months and variances were analyzed according to the Duncan formula (Duncan, 1955).

The equation for the growth percentage formula is

$$= \frac{S2 - S1}{T} \times 100\ \%$$

Where, S1 = first measurement, S2 = second measurement and T = the number of days between each

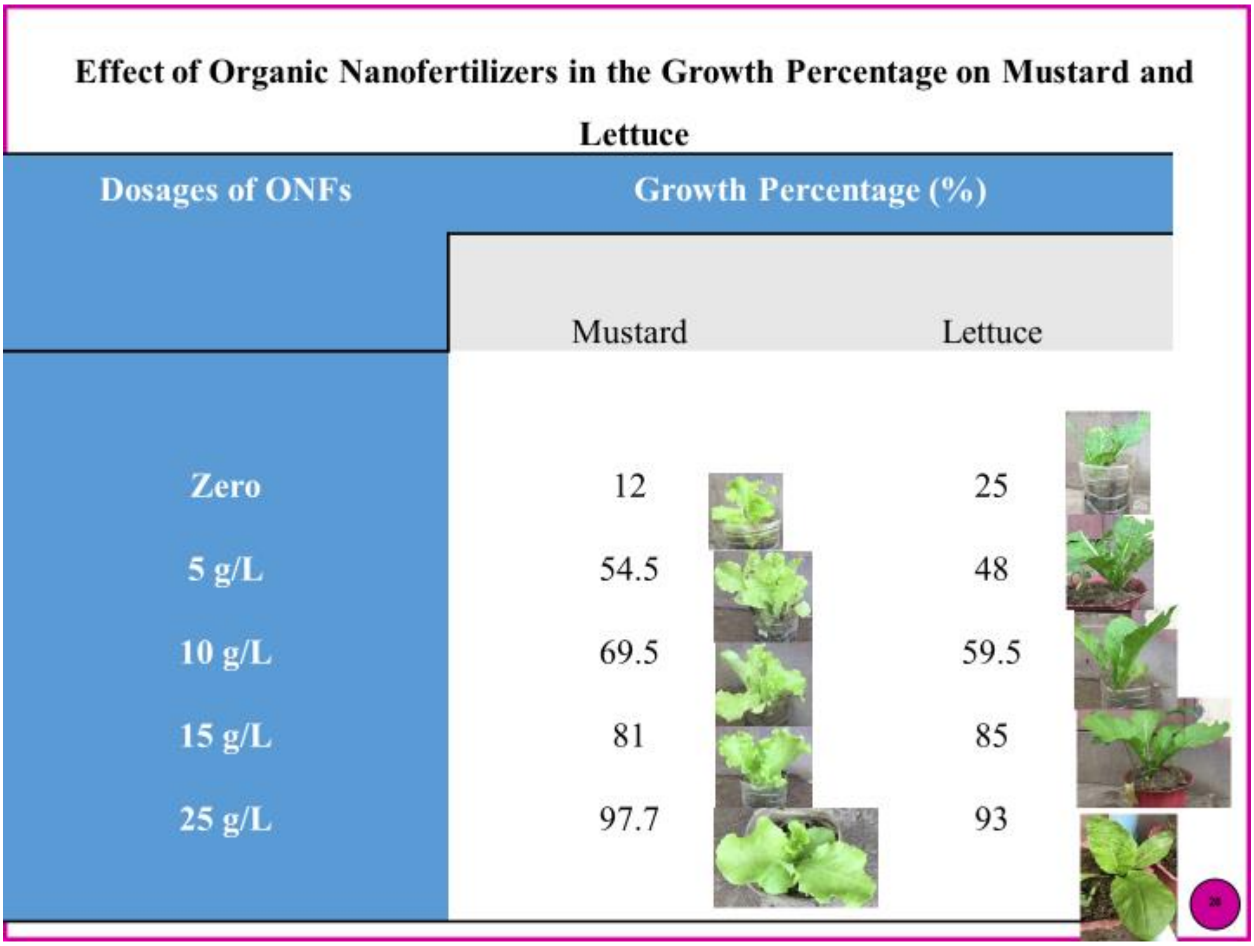

Photo 1. Effect of organic nanofertilizers in the growth percentage on mustard and lettuce.

Results and discussion

Preparation of organic nanofertilizers

Organic nanofertilizers (symbolized as ONFs) were successfully prepared as shown in Figure 1. Firstly, for obtaining banana peels extracts, the banana peels extracts were prepared by cutting, chopping, grinding and filtrating by using a common tap water filter. Secondly, the cow manure extracts were prepared by heating it to get slurry. And each 20 mL of ammonia and potassium hydroxide was used as extracting agents at optimum operating conditions. Finally, the ONFs were produced from the mixing of dried extracts of banana peels and cow manure extracts by using hydrothermal method. The prepared ONFs were collected for further analysis as shown in Fig. 2(b).

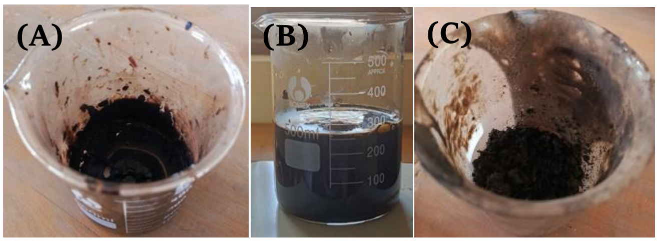

Figure 2. (a) The banana peel extracts, (b) The cow manure extracts and (c) The prepared ONFs.

Physicochemical properties of ONFs analysis

After preparing ONFs, the results of physicochemical characteristics were studied by using of UV-vis, FTIR, EDXRF, XRD and SEM techniques in order to verify the structural formation of produced organic nanofertilizers. NPK contents of ONFs were also evaluated. Moreover, the results of AAS were analyzed for assessing heavy metals contamination in prepared ONFs.

Firstly, the absorption of prepared organic nanofertilizers (ONFs) was recorded by UV-vis spectrophotometry to determine the maximum wavelength absorbed by the sample. The UV–Vis spectrum showed typical absorption peaks at 370 nm and 430 nm, respectively. From this analysis, the first peak at 370 nm is depicted by aromatic and/or unsaturated compounds with an absorption bonds of C=C, C=O and N≡N. While the second absorbance peak at 430 nm reflects the humification of organic matter, indicating the presence of highly humified materials with a high degree of condensed aromatic groups as shown in Fig. 3, which is in correspondence with other reports of organic fertilizers (Biyada et al., 2020).

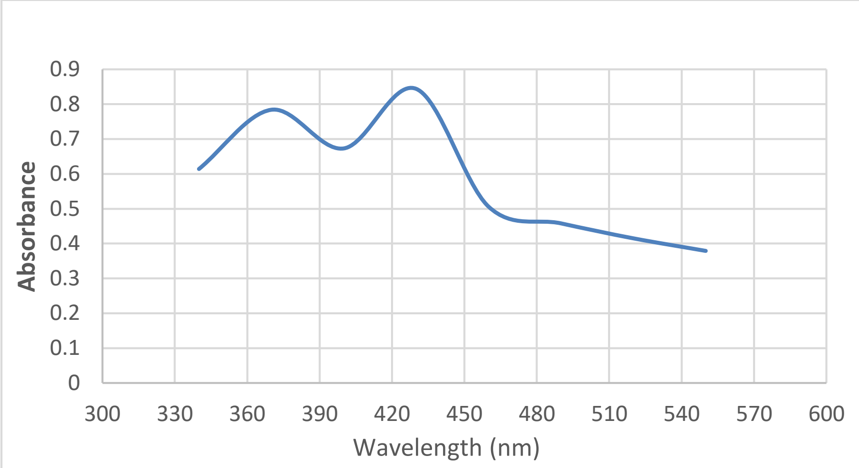

Figure 3. The UV-visible peaks of organic nanofertilizers.

Moreover, functional groups of produced ONFs were confirmed by FTIR to identify important functional groups contained in the prepared ONFs at wave numbers of 400-4000 cm^{-1}. Its FTIR spectrum was reported in Fig. 4. According to the obtained results, the peak at 3256 cm^{-1} exposing a wide and strong absorption band, this can be related to the hydroxyl (OH) and amine (NH) group. Moreover, the emergence of the absorption peaks at 2919.20 and 2848.1 cm^{-1} in the ONFs, which were only faintly noticeable in the FTIR spectrum of ONFs, could be assigned to the symmetric and asymmetric C–H stretching vibration. The signal at 1573 cm^{-1} respecting to C=O bond of the carboxylic group and the band at 1537 cm^{-1} revealing the medium peak which corresponded to N-O stretching groups, are related to the presence of nitrate in the peak, which organic nanofertilizer possessed. Moreover, the peaks at 1259.70 cm^{-1}, 1033.20 cm^{-1}, 777.68 cm^{-1} and 522.20 cm^{-1} were assigned the C–O stretch, PO_4^{3-} asymmetric stretching group, the carbonate (CO_3^{2-}) group, and the presence of Fe–O bending groups due to the interaction of COO-Fe, which was in correspondence with other study (Sebastian et al., 2023).

Furthermore, energy dispersive X-ray fluorescence (EDXRF) was used to evaluate the composition of elements containing in prepared organic nanofertilizers (ONFs). The peaks were shown in Fig. 5. The presence of significant peaks for potassium revealed the formation of potash-rich organic nanofertilizer which was a great deal of potential for promoting high yields for crops. According to Figure 6, the major elemental components of K (53.173%), Cl (14.784%), Ca (13.327%), Si (7.836%), Fe (5.292%) S (1.524%) and Al (1.048 %), respectively. Furthermore, other trace amounts of P, Mn, Ti, Zn, Br, Cu, Sr, Rb and V were detected to be 0.987, 0.935, 0.621, 0.128, 0.104, 0.095, 0.068, 0.067 and 0.010%, respectively. In particular, the major contents of potassium can provide for yielding high value fruit and vegetable farming that increase the crops quality. And calcium is also necessary for forming seeds and fruit and helps protect plants from disease and pests. Moreover, the concentration of silicon in fertilizer has known to improve plant growth and yield especially under biotic and abiotic stresses. The content of iron in fertilizer also plays a key role in manufacturing process of chlorophyll, and it is required for certain enzyme functions (Morya et al. 2022). Sulphur is also an essential plant mineral for helping protein synthesis, enzyme activation, and production of vitamins and hormones. Moreover, trace elements are administered to the plant in various nutrients, including manganese (Mn), zinc (Zn), copper (Cu), strontium (Sr), rubidium (Rb), and vanadium (V). The combination of major elements and these trace elements is important to achieve continuous growth and healthy growth of plants (Kaur et al. 2023).

XRD also provides detailed information about structural information of nanomaterials such as lattice parameters, phase nature, and crystalline structure. In Fig. 6, the XRD pattern of organic nanofertilizer showed its many amorphous shoulder peaks which were not detectable accurately the particle size. It was likely due to the given low temperature of the sample. Nevertheless, the prepared organic nanofertilizer was confirmed its amorphous nature with defect of crystallinity.

Finally, SEM was applied to first determine the structure and morphology of the prepared organic nanofertilizer. The images illustrated the structure of compost that can be used to recognize the layout structure of agglomerated organic nanoparticles produced from combining cow manure and nanoparticles from banana peels. The images indicated that the compost was made up of overlapping layers of organic cow manure particles and nanoparticles which were slightly fluorescent in the top layer. Particles of cow manure and nanoparticles could connect roughly and randomly to homogeneity each other that brought with stable coating structures of microscopic deformations, which have a better nutrient enrichment (Tarafder et al. 2020). This phenomenon is conducive to improving the nutrient enrichment activity for promoting crops growth, especially mustard and lettuce. Moreover, Image J software was utilized to calculate the particle size distribution by measuring several hundreds of particles from the SEM image. According to the calculation, the particle size of prepared organic nanofertilizer was found to be in the range of 64-67 nm as indicated in Fig. 7.

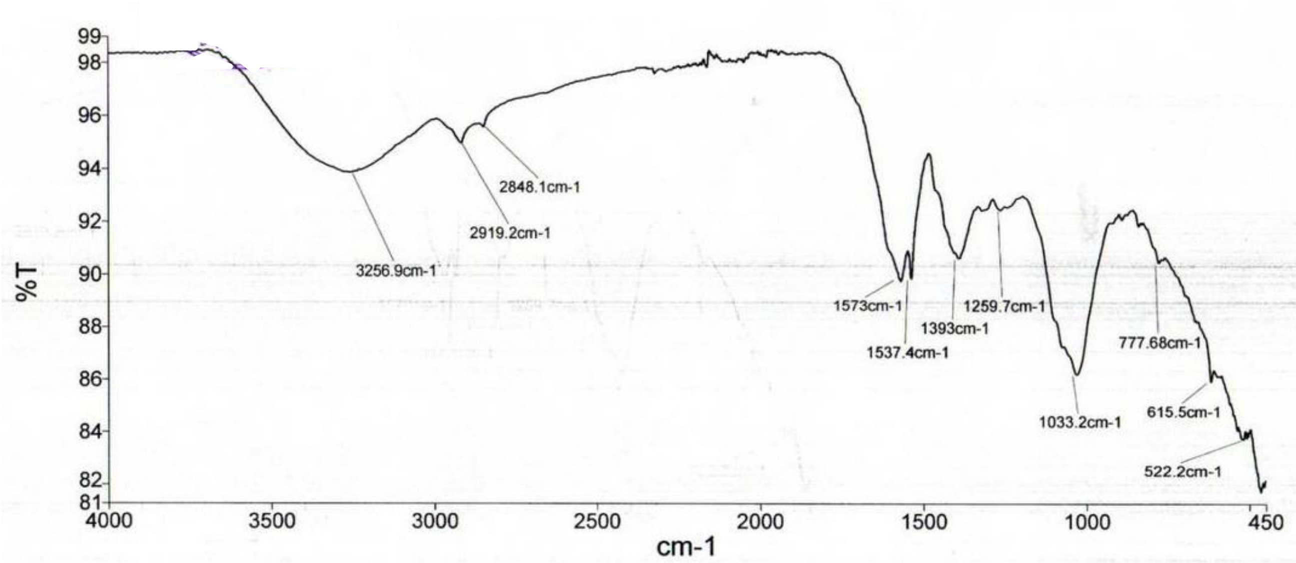

Figure 4. The FTIR spectrum of prepared organic nanofertilizers.

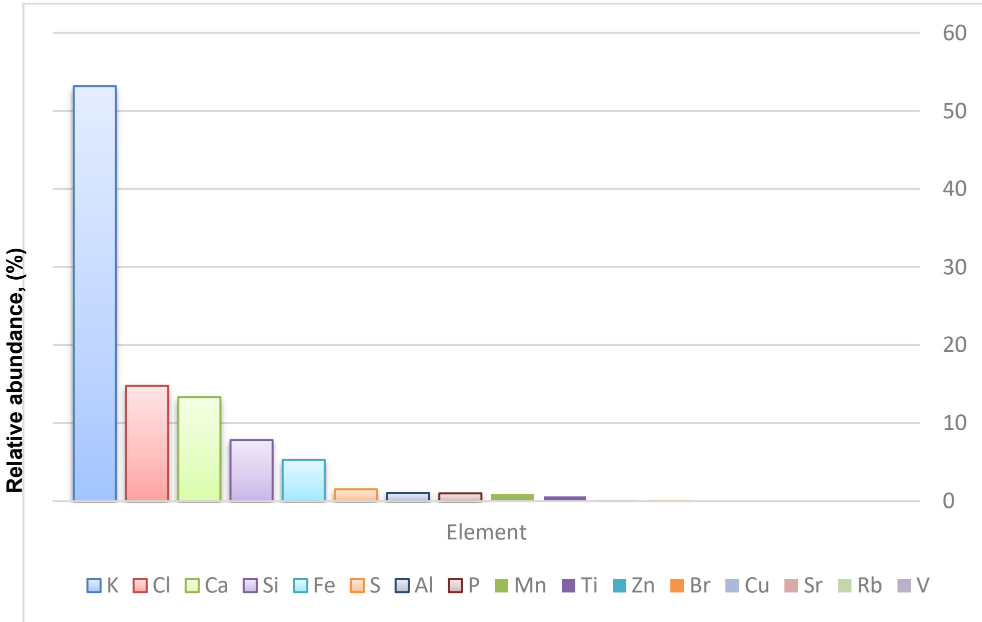

Figure 5. The chart of elemental composition in organic nanofertilizers.

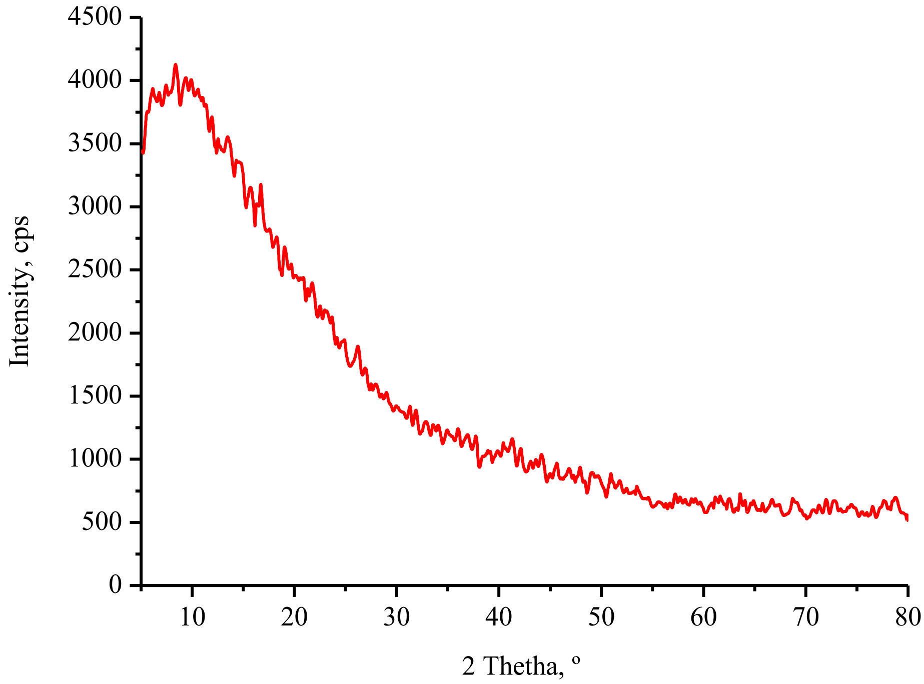

Figure 6. The XRD peaks of organic nanofertilizers.

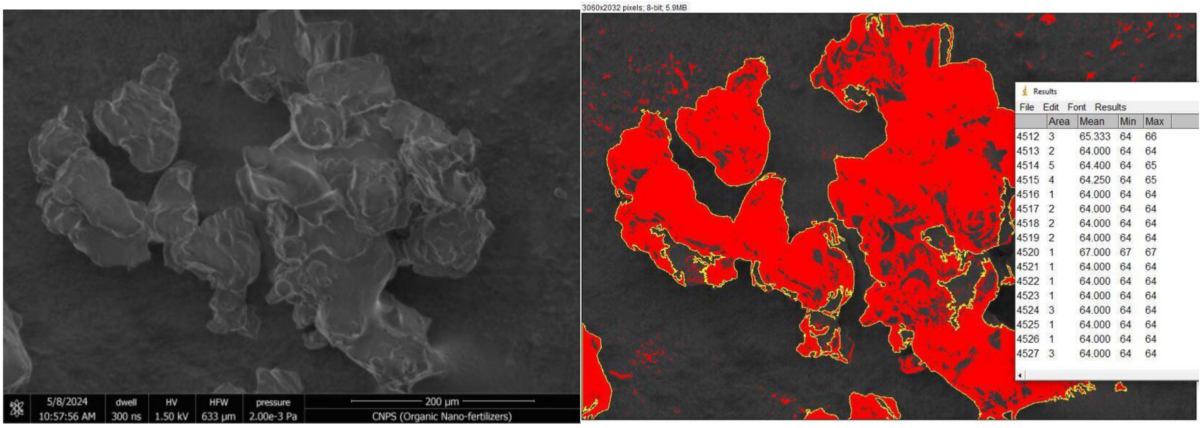

Figure 7. The particle size of organic nanofertilizers reported by Image J software.

Analysis of NPK fertilizers value in prepared ONFs

The NPK ratio represents the percentage composition by weight of prepared fertilizer, each of the percentage composition of N as nitrogen, K as K_2O and P as P_2O_5. As shown in Table (1), the nitrogen, phosphorus and potassium concentrations were found to be 10365 ppm (1.04%), 298.52 ppm (0.03%), and and 20894.7 ppm (2.09%), respectively. The nutrient composition expressed as a ratio on a ppm basis was N:P:K = 34:1:70 ppm in prepared organic nanofertilizers. According to the above-mentioned ratio, potassium content was significantly higher than those of nitrogen and phosphorus. As a result, higher potassium content in these ONFs can help the overall functions of the plant perform correctly (Jiaying et al. 2022). As a second large amount of nitrogen in this prepared ONFs can support vigorous, leafy growth and rich green color. Without enough nitrogen, plants turn pale and growth slows. However, phosphorus is a very small amount in contrast with potassium and nitrogen contents in prepared ONFs. Phosphorus is largely responsible for root growth and flower and fruit development. As a deduction, the organic nanofertilizer prepared in this research would be suitable for all vegetable crops because of significantly optimal content of potassium in prepared ONFs.

Table 1. NPK ratio contents in prepared organic nanofertilizers

Sample	N (ppm)	P (ppm)	K (ppm)
ONFs	10365	298.5200	20894.7000

Determination of organic nanofertilizer by atomic absorption spectrophotometer

Atomic absorption spectrometry (AAS) is a very sensitive method of elemental analysis, allowing the determination of metals in a variety of sample at the picogram level. In particular, some toxic heavy metals content in the prepared organic nanofertilizer has been also determined by the method of atomic absorption spectroscopy (AAS) in this research. According to Table (2), potassium is significantly the highest content of 989.4740 ppm in average value in the prepared organic nanofertilizer, there was evidence that was mostly due to the banana peels extract. The high content of potassium supplied the plant with enough of the nutrient to help the plant become hardier so that it may withstand periods of stress usually occurring in the summer and winter seasons. Furthermore, the iron was found to be 41.279 ppm in average in the sample and it was very important for the growth and health of the plant. It also plays an essential role in metabolic processes such as energy transfer, respiration, and photosynthesis. Iron helps carry important elements through a plant's circulatory system. Moreover, sodium was found to be the third most abundant amounts of 12.8790 ppm in these ONFs. It was not considered an essential plant nutrient, however; certain crops benefit from applications of sodium for sugar beet and fodder beet, grassland and other root crops. Zn was also found as the allowable level in the prepared ONFs. Zinc can also be used in the formation of chlorophyll and some carbohydrates. And it helps plant tissue withstand cold temperatures. The results of other toxic heavy metals such as Cu (copper), Pb (lead) and Cd (cadmium) concentrations were under the maximum allowable level according to the standard of the United State Environmental Protection Agency (USEPA) (Khatun et al., 2022).

Table 2. Elemental contents in prepared organic nanofertilizer

No.	Sample	Met. Time	Cu (ppm)	Zn (ppm)	K (ppm)	Fe (ppm)	Pb (ppm)	Cd (ppm)	Na (ppm)
1	ONFs	X1	0.835	3.114	971.076	41.695	0.703	0.04	12.85
		X2	0.818	2.989	1016.247	41.261	0.761	0.04	12.666
		X3	0.773	2.808	981.099	41.279	0.644	0.058	13.121
		Average	0.8087	2.9703	989.4740	41.4117	0.7027	0.0460	12.8790
		USEPA	10.00	45.00			61.50	10	

Note: Maximum contaminant level in fertilizer indicated by US EPA

Cu = 10.00 ppm, Zn = 45.00 ppm, Pb = 61.50 ppm, Cd = 10 ppm

Application of ONFs in agriculture

On applying ONFs in mustard and lettuce irrigation, it was noticed that the plant growth increased compared with the zero sample as indicated in Table 3. The results may be referred to the high content of nutrients elements such as nitrogen, phosphorus and potassium. The authors investigated other plant growth promoters, for example, as indicated in EDXRF result, iron, silicon and zinc could regulate the plant growth, metabolism of plants under water stress, and increasing physiological availability of water and nutrients, besides the effect of them on increasing growth percentage. As shown in Table 3, it was found that the percentage growth of mustard demonstrated 12%, 54.5%, 69.5%, 81% and 97.7% when dosages of nanofertilizers such as 0 g/L, 5 g/L, 10 g/L, 15 g/ L and 25 g/L were applied. At the same time, the percentage growth of lettuce demonstrated 25%, 48%, 59.5%, 85% and 93% when dosages of nanofertilizers such as 0 g/L, 5 g/L, 10 g/L, 15 g/ L and 25 g/L were applied. Then, it was found that the 25g/L of prepared organic nanofertilizer liquid was the best optimum for mustard and lettuce growth. Therefore, the 25 g of the prepared ONFs was chosen as the optimum value for cultivation of vegetable crops, especially for mustard and lettuce as shown in Fig. 8.

Table 3. Effect of organic nanofertilizers in the growth percentage on mustard and lettuce.

Dosages of ONFs	Growth Percentage (%)	
	Mustard	Lettuce
Zero	12	25
5 g/L	54.5	48
10 g/L	69.5	59.5
15 g/ L	81	85
25 g/L	97.7	93

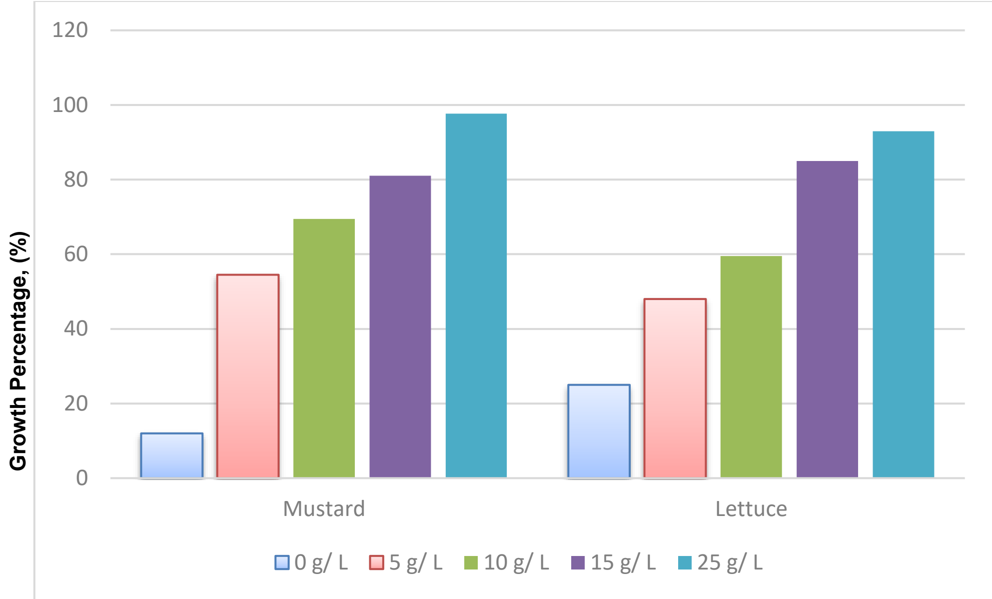

Figure 8. The chart of the growth percentage of mustard and lettuce under applied amount of ONFs.

Table 4. The nanosize in comparison of other studied nanofertilizers with present study.

Extracts	Nanoparticles	NanoSize	Ref.
Ganoderma lucidum extract	Zinc Oxide nanoparticle	-	Sedefoglu et al., 2022
Microalgae	Silver nanoparticles	13-31 nm	Terra et al. 2019
Using microalgal algal extract	Iron-oxide nanoparticles	76.5 nm	Win et al., 2021
Using Lactobacillus casei Subsp. Casei	Copper-oxide nanoparticles	30-75 nm	Kouhkan et al., 2020
Acidophilus, Lactobacillus casei, and Bifdobacterium sp.	Se nanoparticles	100-500 nm	Eszenyi et al., 2011
Cow manure extract	Carbon nanoparticle	64-67 nm	Present study

Conclusion

In summary, the low-cost organic nanofertilizer was successfully prepared from the starting materials of cow manure and banana peels by extraction and hydrothermal methods in this study. Moreover, the starting materials are low-cost and effective. The reaction is not tedious and simple. According to the findings of prepared ONFs, it was found that ONFs possess highly humified organic matter, some important functional groups, 64 nm in size distribution, rich in potassium better nutrient enrichment, favorable contents of nitrogen and non-toxic behavior. Most importantly, the prepared ONFs exhibited satisfying growth percentage of mustard (91%) and lettuce (92%), respectively, while applying 25g/L dose of the sample, in contrast to applying the standard zero dosage of ONFs. Thus, the prepared ONFs demonstrated better growth of sample dosage (25g/L) at adjusted pH 6.5. To sum up, it is anticipated that the prepared ONFs could be used effectively as a growth promoting agent of mustard and lettuce in vegetable crops agriculture according to the results and findings.

Author Contributions
Yaung Kwee: Conceptualization, investigation, methodology, and writing, review, and editing the manuscript.
Van Rem Cawi: Laboratory work.

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Conflict Interest
The authors declare that they have no known competing financial interests that could have appeared to influence the work reported in this research.

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Priprema organskih nano-đubriva kao sredstva za podsticanje rasta senfa i zelene salate

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Apstrakt

U Haki u državi Čin, Mjanmar, senf i zelena salata se gaje u svakom delu grada, bez obzira na godišnje doba, kako za kućnu tako i za vankućnu upotrebu. Đubriva koja koriste uzgajivači su uglavnom konvencionalna. Ne koriste nikakva đubriva koja su naučno pripremljena. U ovoj studiji, organska nano-đubriva (ONF) su sistematski pripremljena od kravljeg stajnjaka kombinovanog sa ugljeničnim nanočesticama proizvedenim od ekstrakata kore banane. Cilj ovog istraživanja bio je da se analiziraju fizičko-hemijska svojstva i da se proceni efekat efikasnosti đubrenja pripremljenih ONF na senf i zelenu salatu. Karakterisana su korišćenjem analitičkih tehnika kao što su UV-vis, FTIR, XRD, EDXRF, SEM i AAS. Takođe je proučavana primena ONF u poljoprivredi. Kao rezultat toga, utvrđeno je da pripremljena ONF imaju UV-vis pik od 430 nm, prečnik 64 nm, potencijalne funkcionalne grupe, visok sadržaj kalijuma i gvožđa u đubrivu, amorfnu prirodu i homogenost sa stabilnim strukturama premaza mikroskopskih deformacija. NPK đubriva su pokazala uravnotežen odnos sadržaja od 34:1:70 ppm u organskim nanođubrivima (ONF), međutim; fosfor je pronađen u veoma malim količinama. Najvažnije je da je procenat rasta senfa i zelene salate uz primenu ONF-a bio 97,7% i 93%, respektivno. Ukratko, nada se da bi se ova organska nanođubriva mogla efikasno koristiti kao sredstvo za podsticanje rasta senfa i zelene salate u poljoprivredi povrtarskih kultura, prema istraženim rezultatima i nalazima.

Ključne reči: kore banana, kravlji stajnjak, ugljenične nanočestice, nanođubriva

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