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Full Length Research Article

GREEN SYNTHESIS OF ECO-FRIENDLY POTASSIUM NANOPARTICLES AND ITS APPLICATION IN *AMARATHUS VIRIDIS, SOLANUM LYCOPERSOCUM* AND *HIBISCUS SABDARIFFA* PLANTS

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ABSTRACT
Potassium Chloride and Polyalthia longifolia leaves extract were used for the synthesis of Eco-friendly Potassium Nanoparticles for application in Amarathus viridis, Solanum lycopersocum and Hibiscus sabdariffa. The synthesized Nanoparticles were characterized by scanning electron microscopy-energy dispersive X-ray (SEM-EDX) and Fourier transform infrared (FTIR). The SEM revealed a size range of 200nm with a near spherical shape synthesized Nanoparticles. Whereas EDX revealed an elemental composition of 19% Potassium, 4.46% Chlorine, 33.04% Carbon, 28.31% Oxygen and 14.30% Iron. FTIR revealed four distinctive at 3235.3cm-1, 2109.7cm-1, 1640.0cm-1 and 1069.7cm-1 for *Polyalthia longifolia* potassium particles (Pl-KNPs). There were significant increase in all the folia applied Pl-KNPs when determined and compared with the controlled plants: Amaranthus viridis leaves recorded the highest increase with 56.81%, Solanum lycopersocum recorded the highest stem increase with 46.15%, while Hibiscus sabdariffa recorded the overall highest percentage with 224.27% attributed to its root length. This distinctive increase observed on the selected folia applied Pl-KNPs plants parameters is a confirmation of the significance of green synthesized potassium Nanoparticles in the field of agriculture.

Keywords: Nanoparticles, *P. longifolia*, fertilizer, *Solanum L*, *Amaranthus V*, *Hibiscus S.*.

INTRODUCTION

Nanotechnology has yielded various dependable nanomaterials synthesis over a diverse range of chemical constitution and sizes (Kaushick *et al*., 2010) and is gaining more relevance as nanofertilizer in agriculture (Rafique *et al.,* 2018: Rizwan, 2019).
A decrease in crop yield has been observed due to factors such as limited rainfall, drought, inadequate bush fallowing resulting in soil fertility decrease, and insufficient organic manure among others (Batsmanova *et al*., 2020). Despite chemical fertilizer application to complement soil fertility and to maximize crop yield, an imbalance between climate regulation, food and feed production, carbon storage and water retention in the ecosystem contribute to soil degradation (Batsmanova *et al*., 2020). To improve soil quality and increase productivity, fertilizer was the solution. Their continuous and intensive usage in crop farming which the crop only ends up using less than 50 % of the applied amount while the other remaining unutilized by the crop is lost through hydrolysis, photolysis, leaching and immobilization of microbial and degradation, thus impacting soil microorganisms, slowing down soil microbial activities, threatening human health and the ecosystem, thereby limiting the profit margin of farmers. For example, 40–60% of nitrogen (N), 70–90% of phosphorus (P), and 50–80% of potassium (K) fertilizers are lost and/or fixed in soils, leading to great economic losses. (Kaningini *et al*., 2022). Environmental restrictions and limited nutrient usage associated with the use of chemical fertilisers continue to be a key issue and obstruction to attaining sustainability in Agriculture.

The method of nanoparticles (NPs) synthesis mediated by plants provides an added advantage of increased life span of NPs that overcome the shortcomings of conventional chemical and fertilizers (Yang and Watts, 2005). Plants metabolites and biomolecules contain carbonyl, hydroxyl and amine functional groups mainly considered responsible for metal ions reduction into NPs (Makarov *et al.,* 2014).
These molecules not only assist in bioreduction of the ions to the nano scale size, but they also play a crucial role in capping the nanoparticles which is salient for biocompatibility and stability. Reducing agents such as, alkaloids, phenolic compounds and sterols can reduce metal ions into NPs in a single reaction. (Usman *et al.,* 2020).

Polyalthia longifolia common names are Mast Tree, Asoka, False Asoka, the Buddha Tree, and Indian fire Tree has been introduced in gardens of many tropical countries across the world even in Nigeria, due to its beautiful appearance and effectiveness in alleviating noise pollution. (Saleem *et al*., 2005). *Polyalthia longifolia* leaves contain appreciable concentrations of Na (30.03mg), K (23.55mg), Ca (89.18mg) and Mg (27.55 mg) (Folashade. *et al*., 2017). *Polyalthia longifolia* is also used in traditional medicine for the treatment of fever, diabetes, skin diseases, helminthiasis and hypertension (Kirtikar and Basu, 1995). *Polyalthia longifolia* possesses significant biological and pharmacological activities, such as antibacterial, antifungal, , anti-ulcer, antitumor and antioxidant properties (Saleem *et al*., 2005).

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Figure 1. Matured *Polyalthia longifolia* plant

Deficiency or inadequate potassium in crops results to spots of dead tissue, yellowing, weak stems and roots. Potassium is essential for meristematic tissue growth and for the preservation of cell turgor pressure, which is necessary for cell expansion (Helen and William, 2023). **S**ome potential advantages of using foliar application of potassium fertilizers on plants include: Rapid and efficient Nutrient Uptake, Increased Nutrient Use Efficiency (Marschner, 2012: Taiz *et al.,* 2015), Balanced Nutrient Supply, Correcting Deficiencies (Gupta and Wu, 1987), Stress Tolerance, Improved Plant Health and Yield: (White and Karley, 2010), Disease and Pest Resistance: (Maathuis, 2014).

Green synthesized potassium nanoparticles (K-NPs) was used on wheat (Pooja *et al.,* 2022). Other foliar applied nanoparticles as nanofertilizers include: iron oxide nanoparticles Fe_3O_4 NPs on Trigonella foenum-graecum and ginger plants (Siddiqui *et al*., 2015: Hao *et al.,* 2018), silver nanoparticles (AgNPs) bean plants (El-Batal *et al*., 2016), silver and copper nanoparticles (AgNPs and CuNPs) on Scots pine and pedunculate oak (Aleksandrowicz-Trzci´nska *et al*., 2018: Aleksandrowicz-Trzci´nska *et al*., 2019)**,** CeO_2 NPs on soybean (Cao *et al.,* 2017), titanium dioxide nanoparticles TiO_2 NPs on *Vetiveria zizanioides*, *Arabidopsis thaliana*, Rice and *Zea mays L*. (Ze *et al.,* 2011: Shabbir *et al*., 2019: Rizwan *et al.,* 2019: Lian *et al.,* 2020). Zinc oxide nanoparticles (ZnO NPs) on wheat, saffron, Sorghum, mung bean, and foxtail millet's (Raliya *et al.,* 2016: Dimkpa *et al.,* 2017: Hussain *et al.,* 2018: Zhang *et al.,* 2018: Kolenˇcík *et al.,* 2019: Rostami *et al.,* 2019)
No literature detailed the synthesis of potassium nanoparticle using aqueous extract of *Polyalthia longifolia* leaf for over a decade, and none of the synthesized nanoparticle was foliar applied on *Amaranthus viridis*, *Solanum lycopersicum* and *Hibiscus sabdariffa* plants.
This study aimed to biosynthesize potassium nanoparticles (K-NPs) and to determine its efficiency as a nanofertilizer on selected vegetables growth and development parameters such as plant height, stem diameter, root length, leaf length and plant weight.
Nano-fertilizers may be a great alternative to dissolvable inorganic fertilizers due to their slow rate of discharging supplements during crop production. Thus, plants would be able to absorb the majority of their nutrient requirements without losses. Besides, improve the nutrients' solubility and dispersion of nutrients in soils is improved by nano-fertilizers, their uptake by plants is also increased. (Batsmanova *et al*., 2020)

Nanofertilizers enhance effective plant absorption ascribed to their foliar application (Scott and Chen, 2013), hence, NPs can substitute the plant nutritive shortage and expand plant production (Ahmad *et al.,* 2019). These may lead to abundant production of valuable nutritious food and can also bring about a rapid and significant progress in the agricultural industry.

2.0 METHODOLOGY

2.1 Sampling and Preparation of Leaf Extracts

Potassium chloride analytical grade was purchased from chemical vendors in Kaduna Central Market, Kaduna North, Kaduna, Nigeria. *Amaranthus viridis*, *Solanum lycopersicum* and *Hibiscus sabdariffa* seeds were obtained from a certified florist within the ministry of Agriculture Kaduna State, Nigeria. Dried leaves of *Polyalthia longifolia* were collected at Sabon Tasha GRA, Kaduna South, Kaduna State Nigeria.
Dried *Polyalthia longifolia* leaves *were washed* with de-ionized water to remove foreign materials, air-dried for 5 days, grinded, and was sieved to obtain a fine particle mesh size. Exactly 50 g of mesh size of about 250-300 microns was weighed and mixed with 250 mL of de-ionized water in a 500 mL beaker, it was then set to boil at 60 °C for 15 min in a water bath. The extract was filtered using a Whatman No. 1 filter paper. The filtered extract was then stored in a refrigerator below 20 ^{o}C for further experiments (Shweta *et al*., 2022).

2.2 Synthesis of Potassium Nanoparticles (K-NPS).

Exactly 14.5 g Potassium Chloride was transferred into a 100 mL volumetric flask and dissolved to the mark. 50 mL of it was transferred into a beaker containing 50 mL of the prepared *Polyalthia longifolia* leaves extract. The mixture was heated to 80 ^{o}C and was continuously stirred using a mechanical stirrer for 20 minutes. 2 mL of 5% sodium hydroxide solution was added to the colloidal solution while stirring until the mixture became intense dark in colouration. It was then centrifuged at 3000 rpm for 30 minutes, placed on an aluminum foil and dried in an oven at 90 ^{o}C for 18 hours, then later transferred into an amber bottle and refrigerated below ^{o}C for further analysis (Ruiz Romero *et al.,* 2018).

2.3 Characterization of Green Synthesized Potassium Nanoparticles (K-NPS).

The refrigerated Green synthesized potassium nanoparticles (K-NPs) was taken to the Multiuser Laboratory of Chemistry Department, Faculty of Physical Science, Ahmadu Bello University Zaria, Kaduna State, Nigeria for characterization

2.3.1 Functional group analysis: the Agilent ATR-FTIR Range 4000 cm-1 to 650 cm-1, was used to analyse functional groups present in *Polyaltha longifolia* leaf extracts and the synthesized potassium nanoparticles (Alankrita *et al.,* 2022).

2.3.2 SEM analysis: SEM images of the nanoparticles was captured to visualize their morphology and surface characteristics (Goldstein, *et al.,* 2003)

2.3.3 EDX Analysis: EDX spectra was analyzed to identify the elements and estimate their concentrations, and elemental distribution on the nanoparticles' surface (Goldstein, *et al.,* 2003; Egerton, 2011).

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2.4 Planting of the *Amaranthus Viridis*, *Solanum Lycopersicum* and *Hibiscus Sabdariffa* Seeds.

Six pots of nursery beds were prepared for planting of *Amaranthus viridis*, *Solanum lycopersicum* and *Hibiscus sabdariffa* seeds. At week two after germination, the synthesized potassium nanoparticles, 100 mg/mL was applied on the plants by folia spray once at four (4) days interval for a period of sixteen days. A week after the final application, it was harvested to determine the average mean in triplicate of the Plant total weight, Plant height, Leaf length, Root length and Stem diameter (Boora, *et al*., 2021).

2.5 Determination of *Amaranthus Viridis*, *Solanum Lycopersicum* and *Hibiscus Sabdariffa* Parameters Growth

2.5.1 Plant Height: The vertical distance from the base of the plant to the tip of the highest leaf was measured using a measuring tape to obtain the height. (Lakshmanan *et al.,* 2015)

2.5.2 Stem Diameter: A representative stem was selected and its diameter was measured using a caliper, the widest part of the stem perpendicular to its axis was the part given consideration. (Martin and Juniper, 1970).

2.5.3 Leaf Length: Mature and healthy leaves from various parts of the plant were chosen, the length of the leaf blade from the base to the tip was measured using a ruler (Salisbury and Ross, 1991).

2.5.4 Plant Weight: The plants were harvested carefully to avoid damaging the roots, it was separated into different parts (leaves, stems, roots) and each part was weighed using analytical balance (Bhardwaj and Sharma, 2015).

3.0 RESULTS AND DISCUSSION

3.1 Atr-Ftir *P. Longifolia* Extract and Potassium Nanoparticles (KNPS)

From figure 2, the prominent characteristic peaks at 3928.6 cm^{-1}, 3574.5 cm^{-1}, 3507.4 cm^{-1}, 3280.1 cm^{-1}, 2922.2 cm^{-1}, 2855.1 cm^{-1} were assigned to Amine N-H stretching, alcohol and carboxylic acid O-H stretching, C-H stretching of terminal alkyne, vinyl, alkane and aldehydes. Peaks observed at 2363.1 cm^{-1}, 2284.9 cm^{-1}, 2117.1 cm^{-1}, 2012.8 cm^{-1}, 1912.1 cm^{-1}, 1621.4 cm^{-1}, 1520.8 cm^{-1}, 1438.8 cm^{-1} and 1375.4 cm^{-1} were assigned to C=C, C=N, C=C=C, C≡C, C≡N, stretching vibration of alkyne, alkene, benzene and aline, while the peaks observed at 1319.5 cm^{-1}, 1241.2 cm^{-1}, 1159.2 cm^{-1}, 1028.7 cm^{-1} were assigned to C-O stretching, –CH2- bending vibrations, and 704.5 cm^{-1}, 670.9 cm^{-1} for alkyl halides (Aleksandrowicz-Trzci´nska *et al*., 2018: Aleksandrowicz-Trzci´nska *et al*., 2019: Siddiqui *et al.,* 2015).

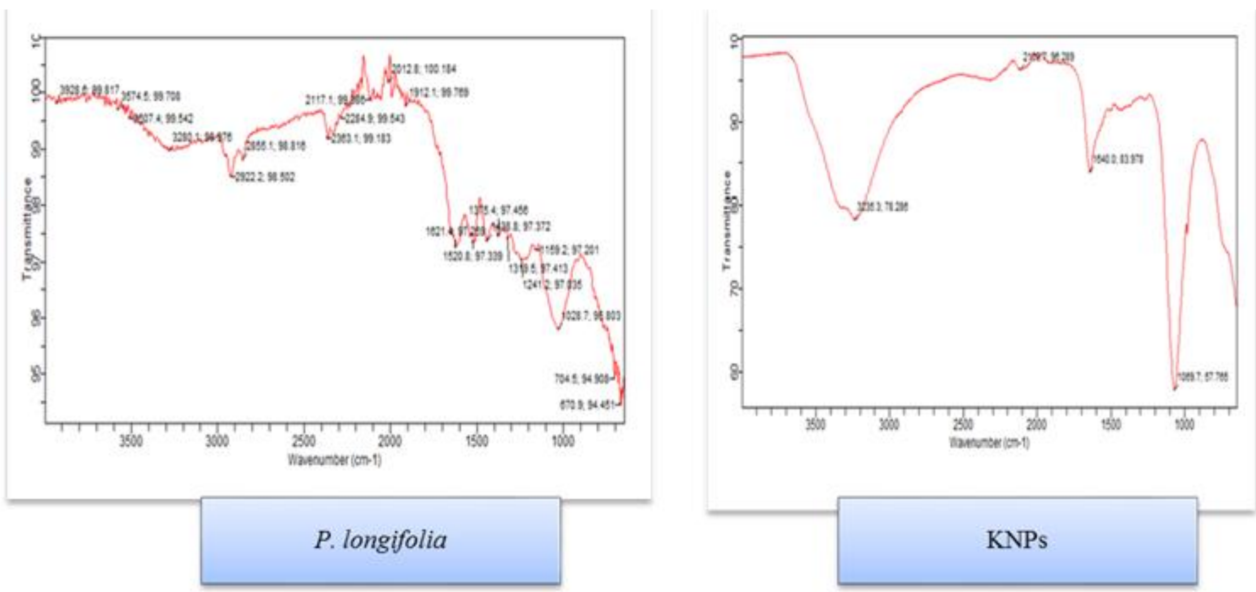

Figure 2. ATR- Fourier transform infrared spectroscopy of *P. longifolia* extract and potassium nanoparticles (KNPs)

Four distinctive peaks only were observed for *P. longifolia* potassium nanoparticle (KNPs), at 3235.3 cm^{-1} assigned to O-H stretching or terminal ≡C-H stretching, 2109.7 cm^{-1} assigned to C≡C, C≡N, stretching vibration, 1640.0 cm^{-1} for alkene C=C stretching and 1069.7 cm^{-1} for C-O stretch. The increase and decrease in wave number were observed in the four peaks shown in Figure 2, for KNPs. This might be due to conjugation, resulting from the synthesis temperature and/or the addition of sodium hydroxide. It was also observed that the remaining functional groups shown in *Polyathia longifolia* extract from Figure 2, were missing and no longer found in KNPs. These missing functional groups and others with reduced and increased wavenumber are possibly responsible for the reduction, capping and stabilization of the synthesized *Polyathia longifolia* potassium nanoparticle (KNPs), (Siddiqui *et al.,* 2015; Aleksandrowicz-Trzci´nska *et al*., 2018: Aleksandrowicz-Trzci´nska *et al*., 2019). This results is in conformity with the plant mediated synthesis of Potassium Nanoparticles by Judith *et al.,* (2021), plant mediated synthesis of copper nanoparticles by Maulana *et al.,* (2022), and biosynthesis of magnetite nanoparticles by Shweta *et al.,* (2022).

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3.2 Scanning Electron Microscope (SEM) Micrographs and Energy Dispersive X-Ray (EDX) Analysis of Synthesized K-NPS

The Scanning Electron Microscope (SEM) micrographs of synthesized KNPs in Figure 3, showed that the KNPs is near spherical in shape with average particle size of 200 nm. Non uniform distribution and agglomeration of nanoparticles was observed, which may be due to the concentration of the precursor used, biomolecules and secondary metabolites present in *Polyalthia longifolia* leaves extract as it contains many naturally derived polyphenolics and many cyclic aromatic compounds with good reducing capacity. The high antioxidants and polyphenols in *Polyalthia longifolia* leaves makes it a good choice for biosynthesis of KNPs. (Katka *et al., 2010:* Judith *et al.,* 2021). Similar result was shown by (Judith *et al.,* 2021) in the synthesis of Potassium Nanoparticles from *Sideroxylon Capiri*. Biogenic synthesis of potassium nanoparticles by (Sheoran *et al.,* 2021), biosynthesis of Cu nanoparticles using *Polyalthia longifolia* roots extracts (Maulana *et al.,* 2022), the biosynthesis of magnetite nanoparticles from *Polyalthia longifolia* leaves (Shweta *et al.,* 2022), in Synthesis of silver nanoparticles employing *Polyalthia longifolia* leaf extract (Dashora *et al.,* 2022). The particle size obtained in this literature was higher than that of (Maulana *et al.,* 20), (Dashora *et al.,* 2022*)* and was lower than that of (Shweta *et al.,* 2022). This could be as a result of the precursor used or the reaction conditions of the synthesis.

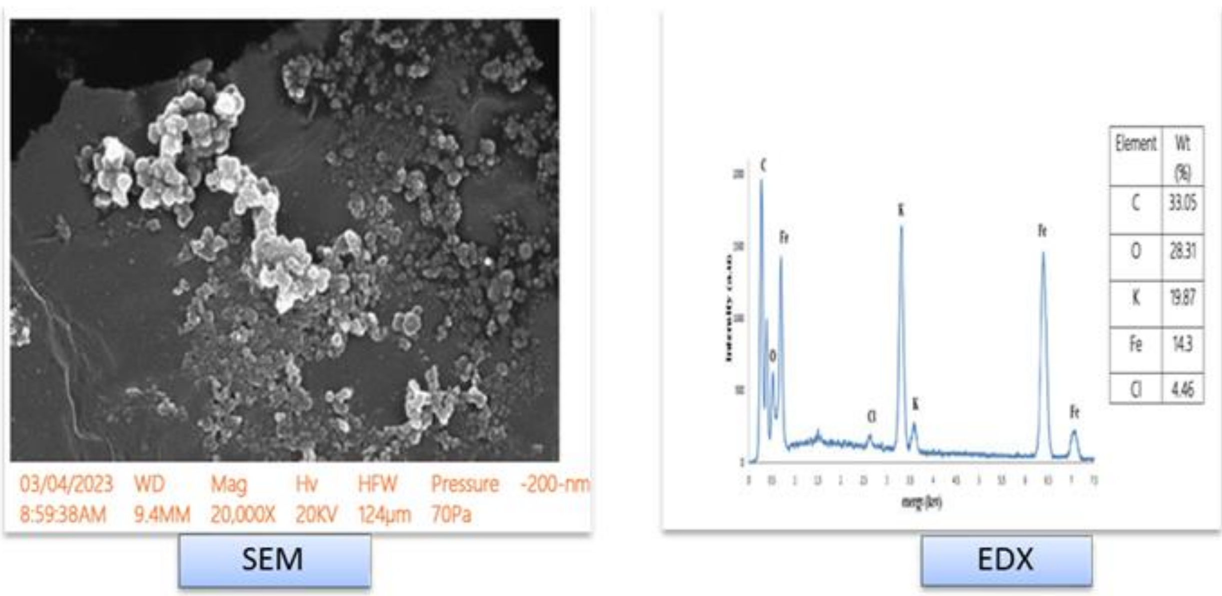

Plate 3. SEM-EDX of synthesized *P. longifolia* potassium nanoparticles, KNPs.

Energy dispersive X-ray (EDX) aanalysis to determine the elemental composition of the synthesized nanoparticles. Figure 3.2 above revealed the presence of pure K (19%), followed by peaks of Cl (4.46%), C (33.05%), O (28.31%) and Fe (14.30%). A good percentage of Fe atoms were observed on the surface of the potassium nanoparticles. This might be due to the plant leaves extract used, or impurity from the precursor or from the 5% sodium hydroxide used in the synthesis process. (Rajonee *et al.,* 2017: Shweta *et al.,* 2022). According to the EDX result, the green synthesized KNPs also produced a strong signal at 3.3 keV as shown in Figure 3.2, which confirmed the existence of K and the organic components present in plant biomaterials on the surface of the synthesized nanoparticles. Similar result was shown by (Judith *et al.,* 2021: Sheoran *et al.,* 2021). Although, results by (Sheoran *et al*., 2021) was higher than that of (Judith *et al.,* 2021) and the one used in this study which might be due to the potassium precursor used.

3.4 Plants Selected Parameters Development.

As shown in Table 1, the KNPs foliar applied *Amaranthus viridis*, *Solanum lycopersicum* and *Hibiscus sabdariffa* were seen to have an intense green colouration signifying a higher chlorophyll pigment when compared with the controlled. This is because potassium is crucial in photosynthesis as it is involved in the synthesis of chlorophyll, contributing to healthy and vibrant foliage. A confident structural integrity of the foliar spray plant was also observed due to the contribution of potassium towards the strength and rigidity of plant cell wall, including those in the stem preventing them from becoming weak and brittle (Boora, *et al.,* 2021: Pooja *et al.,* 2022). Similar results was shown by Titanium oxide nanoparticles TiO_2 NPs (Shabbir *et al*., 2019: Rizwan *et al.,* 2019), Zinc oxide nanoparticles ZnO NPs, (Dimkpa *et al.,* 2017: Hussain *et al.,* 2018: Rostami *et al.,* 2019).

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Table 1. Development parameters of *Amaranthus viridis*, *Solanum lycopersicum* and *Hibiscus sabdariffa plants*

Solanum Lycopersicum			
Plant Parameters	**Control**	**K-NPs**	**% Increase**
Plant Height (cm)	17.70	22.80	28.80
Root Length (cm)	3.02	9.50	14.60
Leave Length (cm)	3.60	4.45	23.61
Stem Diameter (cm)	1.30	1.90	46.15
Plant Weight (g)	27.80	35.30	26.90
Amaranthus viridis			
Plant Parameters	**Control**	**K-NPs**	**% Increase**
Plant Height (cm)	11.90	17.75	49.10
Root Length (cm)	7.65	12.05	36.36
Leave Length (cm)	6.60	10.35	56.81
Stem Diameter (cm)	1.10	1.50	36.36
Plant Weight (g)	11.90	16.60	39.40
Hibiscus sabdariffa			
Plant Parameters	**Control**	**K-NPs**	**% Increase**
Plant Height (cm)	16.30	19.25	18.80
Root Length (cm)	7.58	17.0	224.27
Leave Length (cm)	6.35	6.75	6.29
Stem Diameter (cm)	0.85	1.05	23.52
Plant Weight (g)	7.81	8.30	6.30

In table 1, KNPs fertilized plants showed an increase in plant weight by 26.90 %, plant height by 28.80 %, root length by 14.60 %, leave length by 23.60 % and stem diameter by 46.15 %. When compared with the controlled for *Solanum L*, an increase in plant weight was recorded by 39.40 %, plant height by 49.10 %, root length by 36.36 % leave length 56.81 % and stem diameter by 36.36 % as compared to the controlled for *Amaranthus V* and also an increase in plant weight by 6.30 %, plant height by 18.8 %, root length by 23.52 % leave length 6.21 % and stem diameter by 23.52 % when compared with the controlled for *Hibiscus sabdariffa* respectively. This results are in line with the results revealed by (Pooja and Sudha 2022) where in seed priming the application of green synthesized K NPs at 60 ppm for 8 hours recorded significantly higher root length (12.93 cm), shoot length (6.78 cm), root volume (0.72 cm3), seed germination (96.67%) and root diameter (0.34 mm). Likewise, (Sheoran *et al*., 2021) results recorded an increase of 20.99 % in plant height and 65.66 % in root length upon application of 60 ppm of *Morus Alba* KNPs on wheat (Hussain *et al.,* 2011) in the growth and yield response of two cultivars of mungbean (*Vigna radiata L.*) to different potassium levels where potassium fertilization had the stimulatory effect on yield as well as plant height. (Zelelew *et al.,* 2016) in the effect of potassium levels on growth and productivity of potato varieties reported increase in leaf number, plant height and aerial stem number in potato plant after potassium fertilization.

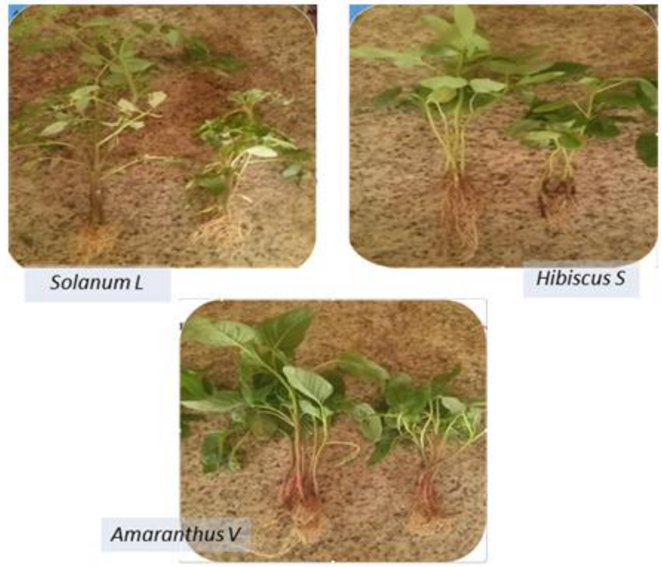

Figure 4: *Solanum lycopersicum, Hibiscus sabdariffa and* Amaranthus *viridis* foliar spray K-NPs (Left) and Control (Right).

Also, from Figure 4 and Table 1, it was observed that not all plants part showed direct and significant increase upon KNPs application, in *Amaranthus V*, the most noticeable parameters with great difference were both the Leave length and the plant height with a percentage increase of 56.81 % and 49.10 % thus favouring the edible part of the plant. This implied that *Amaranthus V* is a wholly consumable vegetable with the exception of the roots. While for *Solanum L,* the stem recorded a diameter of 46.15 % while the plant height had 58.80 %, thus showing that the succulent nature of the plant stem gives balance and strength to be able to carry the plant weight as the increase height will favour the formation of more new branches that will bear more fruit which in turn will need the stem strength to carry the plant weight and to withstand external forces like wind. In *Hibiscus sabdariffa,* the stem diameter increase was 23.52 % while the root length showed a percentage increase of 224.27 % this increase is attributed to the nature of the plant as *Hibiscus sabdariffa* is a tall plant that grows over 2 meters long, a good stem diameter will give the plant stability and flexibility to withstand external forces while the root length gives the plants ability to withstand drought due to the longer life span of the plant and its ability to absorb sufficient water and nutrients to sustain the plant (Bose *et al*., 1998: Kirtikar and Basu, 1995). Similar results were shown by (Hussain *et al.* 2011; Abdel-Aziz *et al*., 2016: Zelelew *et al.* 2016: Hasanuzzaman *et al.,* 2018: Sheoran *et al*., 2021).

Conclusion

Potassium nanoparticle near spherical in shape and a size of 200 nm was biosynthesized using *P. longifolia* leave extract for foliar application on three plants *Amaranthus V*, *Solanum L and Hibiscus sabdariffa.* KNPs FTIR showed the presence of functional groups responsible for capping and stabilizing the nanoparticles. Scanning electron microscopy (SEM) revealed a size range of 200 nm and a near spherical shape. Energy dispersive X-ray (EDX) revealed an abundance of 19.00 % Potassium and 4.44% Chlorine making it a suitable choice for application as nanofertilizer. There were significant increase in all the plant parameters determined between

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the control and the foliar applied KNPs. Amaranthus *V* leaves length showed the highest for the plant parameters measured at 56.81 %. *Solanum L* highest increase was recorded at the stem diameter with 46.15% while *Hibiscus sabdariffa* had the overall greatest percentage increase of 224.27 % attributed to its root length. These distinctive increase observed on the foliar applied plants confirmed the significance of biosynthesized nanofertilizer in agriculture

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Conflicts of interest
No conflict of interest associated to this work.

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