Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Spl Issue [3] 2022: 310-316

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

REVIEW ARTICLE **OPEN ACCESS**

Applications of Potassium Nanoparticles and their Evaluation as Growth Promoter in Wheat

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ABSTRACT
For plants, Potassium is the crucial nutrient that contribute leading role in increasing, harvesting, expansion, metabolism, in addition to managing enzymatic activity and controlling physiological functions of plants .The interaction between nanoparticles (NPs) and plants importantly stimulating the expansion of research fields like nanotechnology, agriculture, food science, electrical engineering and biomedicine. On the contrary, nanotechnology has been extensively used in plant studies since NPs can serve as growth regulators, pesticides, fertilizers, antimicrobial agents, biosensors, and plant mimics. Additionally, plants can lead to the expansion of nanotechnology as well as the composition of NPs and plant-stimulating nanobionics. A considering of the distinct aspects of the interaction between NPs and plants is favourable to build additional achievements although presently there is still relatively little literature discussing this interplay. In this review, we provide a moderately comprehensive overview on the interaction between NPs and plants from two aspects: (1) how NPs constitute for plants where NPs can operate as plant hormones, toxicant, composts, germicide agents, targeted carrier, Nano-fabrications, and plant imitators; and (2) how plants leading the expansion of nanotechnology where plants can be utilized for the biogenesis of NPs and encouraged human to mimic nature.
Keywords: *Nanoparticles, Nano bionics, Germicide agents*

Received 21.08.2022 Revised 29.09.2022 Accepted 24.11.2022

INTRODUCTION

Nano basically states that reduce to nanometre (nm). The dimensions of nanoparticles (NPs) vary from 1 nm to 100 nm, even if they are in gaseous, liquid or solid state [1,2]. The term "NPs" have not come out before the arrival of nanotechnology in 1960s, but NPs certainly occur in nature for thousands of years. NPs have unique prospects since their "apparent effect", "minute effect", "significant effect", and "macroscopic quantum tunneling effect". When particles are decreased to Nano scale, not merely the number of surface atoms but also the range and energy of surface will grow promptly. Particles reveal remarkable properties when their sizes are down to nanometres. For example, electrons on the covering of NPs can merge with light. The frequency of light is equivalent to surface electrons oscillation; the light will be consumed by NPs, dominating to a surface plasmon resonance (SPR) phenomenon. According to their distinctive properties, NPs have starved substantial recognition from researchers across multiple disciplines owing to their potential applications in physical, chemical, biological and healthcare fields [3]. Up till now, NPs have been widely applied in auto, architecture, textile, electronic information, and medical industries [4-8].

Plants are one of the most remarkable forms of life, along with trees, shrubs, flowers, grasses, ferns, green algae and lichens. They are beneficial in a multiple of applications in fiber, oil essence, dyes, resin and other chemical raw materials. Besides, living plants can be utilized for green carving, bonsai and flower arrangement. Further certainly, as the primary producer in terrestrial ecosystem, plants required most of the nutrients necessary for human survival. For example, sugar is mostly mined from sugar cane and beets. Edible oils originate from corns, soybeans, sunflowers and olives. But, with the worsening of

living environment, plants express various harmful symptoms like leaf rust, abnormal fallen leaves and slow growth, leading to a decrease of yield.

The expanding nanotechnology can offer an encouraging platform to direct these issues. NPs have been useful in plant kingdom as the very beginning of 21st century, being the interaction between plants and nanotechnology has been broadly studied with the progresses in nanotechnology. On the contrary, NPs can enrich to the plants. Originally, NPs can serve as growth regulators, pesticides, fertilizers, and antimicrobial agents. Including the expansion of nanotechnology, nanomaterial have moved further into cytoplasmic matrix and even organelles in plants, and enabled instantaneous monitoring of particular biomolecules. What's more, Nano scale materials can be operating to imitator including the composition and function of chloroplasts in plants. Additionally, plants can also progress the development of nanotechnology. As vast resources in nature, plants can be used for the preparation of NPs either in a manner of direct extraction or in a manner of plant-mediated biosynthesis. Further, plants in nature provide an encouraging platform for Nano bionics that importantly encourage researchers to consider Nano electronics. The interaction between NPs and plants is of prominent acceptance that can encourage the expansion of various research fields including agriculture, food science, nanotechnology, electrical engineering and biomedicine. Though, there is quiet moderately slight literature covering the interaction of NPs and plants. A considering of the multiple aspects associating NPs and plants is crucial to make additional accomplishments in this field. In this review, we consequently offer a comparatively wide-ranging overview on the interaction between NPs and plants from two phases: (1) how NPs aid plants where NPs can perform as growth regulators, pesticides, fertilizers, antimicrobial agents, targeted transporters, biosensors, and plant mimics; and (2) how plants spread the expansion of nanotechnology where plants can be recycled for the research of NPs in a way of either direct extraction or plant-mediated biosynthesis, and inspire human to mimic nature

NPs for plants

The expanding nanotechnology has stimulated much attention among researchers in various fields such as medicine, chemistry and biology. As one of the most important branches in biology, plant is vital to human life. Developments in nanotechnology have reformed and will proceed to influence the plant studies. Maintaining to the nanostructure and their remarkable properties, NPs can be conveniently expressed into plant cells and even organelles. This part direct to analysing the various roles of NPs in plant studies where NPs can operate as growth regulators, Nano-pesticides, Nano-fertilizers, Nano antimicrobial agents, targeted transporters, biosensors and Nano mimics in plants.

Characterization of potassium nanoparticles was done by several techniques like Dynamic Light Scattering Analysis, Transmission Electron Microscope Analysis, Atomic Force Microscopy Analysis, Electron Dispersive X-Ray Spectroscopy and Field Emission Scanning Electron Microscope.

1 Dynamic Light Scattering (DLS) Analysis Dynamic light scattering (DLS) is greatly implementing technique which is intraoperative and utilized for the quantification of the size, zeta potential as well as size distribution of particles in a wide range of particle size. Particles or molecules in suspension cause Brownian motion which dispersed laser light at different intensities. These intensity fluctuations give the velocity of Brownian motion and size of particles was obtained by applying the Stokes-Einstein relationship. Particle size analyser (Zetasizer Nano series Nano-ZS90, Malvern Instruments) was used for size measurement and confirmation of nanoparticles size distribution along-with measurement of zeta potential.

2 Transmission Electron Microscope Analysis Journal Pre-proof Journal Pre-proof 6 TECNAI 200 kV TEM (Fei, Electron Optics) was used for determining the physical dimensions of potassium nanoparticles. This instrument is capable of high resolution EELS (Electron Energy Loss Spectroscopy) for analysis of bonding state on a nanometre scale. Drop coating method was operated for sample preparation. A particle of suspension holding nanoparticles was deposited on the carbon-coated copper grids and dehydrated for overnight under vacuum desiccators. The sample was placed on sample holder and specified.

3 Atomic Force Microscopy Analysis AFM was preferred to obtain three dimensional image and surface measurements. AFM practices a cantilever with a sharp tip that examine over the sample surface. A particle of suspension holding nanoparticles was deposited on glass slides and dehydrated with the help of desiccator. Sample was placed on specimen holder and analysed using Park NX1O AFM. Here tapping mode with closed loop 20 x 20 µm scanner was used for potassium nanoparticles analysis.

4 Electron Dispersive X-Ray Spectroscopy (EDS) Elemental analysis of single particles was drifting out using Liquid Nitrogen Free 129 eV 100 mm 2 crystal area on SEM, a scanning el

ectron microscope Leo 435 VP (Carl Zeiss Inc, Oberkocken, Germany), equipped with EDS. Here carbon coated copper grids were utilizedfor sample preparation and dehydrated at room temperature for

elemental analysis. It is greatly used for resolute the elemental composition also the purity level of the NP sample by atom percentage.

5 Field Emission Scanning Electron Microscope (FESEM) A Field Emission Scanning Electron Microscope works with electrons (particles with a negative charge) instead of light. With field emission source electrons are released. The object is examined by electrons according to a zigzag pattern. FESEM is designed to examine surface structures and sub-surface structures of specimen which are located in evacuated specimen chamber. Here surface analysis of potassium nanoparticles was envision by Merlin Compact Field Emission Scanning Electron Microscope (FE-SEM) from Carl Zeiss, Germany which can be used to visualize surface morphology up to 2 nm resolutions..

Nanoparticales using plant extracts

The utilization of plant extracts to generate metal nanoparticles useful in electronics, medical purpose and biotechnology, is an area of achievement. These nanoparticles have small uncertain issues to the surroundings and low virulent for the human body [3]. Plants and phytochemicals perform the dual purpose of being a natural reducer for nanoparticle production as well as the nanoparticle preservative [9]. Plant manufactured nanoparticles are further more constant regarding mass and nature. Additionally, the harvest of this technique is much beneficial than the other ones like electrochemical reduction, chemical reduction, heat evaporation and photochemical reduction [10]. It recruits the different types of nanoparticles produced. Nanotechnology for maintainable crop growing. The procedure of nanotechnology in maintainable crop cultivation deals the proficiency for considerably improved agricultural productivity and harvest with cheap cost and less unwanted manufacturing [11]. Nano-biotechnology influences the genes by using nanoparticles, nanofibers and Nano capsules. Expenditure of nanotechnology in crop biotechnology can develop the entire setup of the existing agricultural industry. Novel tools are industrialized for diligence farming, Nano biosensors and Nano filtrations for the study of several environmental conditions, quick detection of phytopathogens, cultivating water quality for irrigation by plants and their practices.

Carbon nanomaterial using natural sources as precursors

Vegetable oil has established itself to be a realistic precursor for carbon nanotubes. By this approach, mutually single-walled and multi-walled carbon nanotubes can be produced using diverse catalysts [13]. Sugars and biopolymers have been operated as precursors for carbon quantum spots by resources of a microwave approach [11]. Green synthesized nanomaterial are being used for various applications in field of growth and development of plant, harvest improvement, photosynthesis, fertilizers, pest control and postharvest technology, physical aspects such as Nano sensors, Nano filtration, diligence farming, fictitious nanoparticles. Several of these fields consume green synthesized nanoparticles though others still depend on chemically synthesized nanoparticles.

Nanotechnology in insect pest management

Pesticides are organic substances recycled to regulate pests. However, common of the currently employed pesticides are uncertainly soluble in water or their solutions need solvents which are exclusive, combustible and lethal, while the others are emulsification which involves high-energy input. To contract with these downsides, constructions derived from micro- and Nano emulsions have been phased in agro industry. The manipulation of nanoparticles as maintainable release system could supplement the efficiency of pesticides while decreasing their inauspicious environmental effects. Nanoparticles act as 'Nano carrier' thereby proving to be a well-organized transport system those transmissions a accurate biomolecule to the cell, tissue or organism when mandatory [14]. Nano carriers have well-organized filling potential owed to enormous surface area, uncomplicated devotion of molecules of pesticide and rapid replacement to targeted insect body. These Nano carriers are the nanoparticles established on polymers, Titania, copper, synthetic silica, silver and some natural Nano-minerals. The silica nanoparticles destroy the insect pest by distracting the cuticle as they get engaged by the lipids. Silica nanoparticles can be practical directly to the fields and performed as pesticides or can be used as Nano carriers to discharge commercial pesticides.

Nanotechnology for sustainable crop cultivation

The usage of nanotechnology in maintainable crop cultivation deals the capability for considerably enriched agricultural productivity and harvest with summary cost and reduces waste production [15]. Nano-biotechnology operates the genes by using nanoparticles, nanofibers and Nano capsules. Practice of nanotechnology in crop biotechnology can develop the whole set-up of the current agricultural industry. New tools are established for diligence farming, Nano biosensors and Nano filtrations for the study of several environmental conditions, quick detection of phytopathogens, refining water quality for irrigation

Nanotechnology in plant growth and development

Plants require several crucial nutrients (macronutrients and micronutrients) for vigorous evolution and crop. If there is deficient one of those crucial constituents, then the plant are not capable to develop from

the seed appropriately [17]. Though, the occurrence of an additional amount of nutrients can also damage plants. A sufficient supply of these nutrients to come across the demands of the elementary cellular process is a inspiring matter. Consequently an appropriate and definite transfer of nutrients is seriously mandatory for plants to broad their life cycle. When the mineral nutrients were engaged by the plants have several roles to perform in the plant's body [18]. They can maintain to generate and establish plant tissue. They are the components of several proteins, pigments, enzymes, and elaborate in cell signalling and metabolism. Till now 17 elements (N, P, K, H, B, C, O, Mg, S, Cl, Ca, Mn, Fe, Ni, Cu, Zn, and Mo) have been recognized as crucial nutrients for plant growth and development. Between them, nitrate, phosphorus, potassium, magnesium are utmost important necessary elements desired by the plant. They cannot be immersed directly from the atmosphere, but plant ingest them through their roots[22]. Consequently, the Nano scale-dimension of Nano fertilizers has develop a technical solution for nutrient lack problems. Nano fertilizers are self-possessed of numerous nanoparticles comprising metal oxides, carbon-based, and other nonporous materials fluctuating upon their configuration and mixing properties[20]. It can be manufactured by top-down (physical), bottom-up (chemical), and biological methods. It was termed that the Nano fertilizer is accomplished to afford slow-release function, precise supply of different macro and micro-nutrients to plants with definite concentrations, accurate size, and extra surface area. The reaction of plants by engrossing nutrients from the soil be determined by the morphology and producing criteria of numerous nanoparticles. Over years of research founded on specific nutrient supplies, it is probable to promote different types of Nano-fertilizers like micronutrient Nano fertilizers, macronutrient Nano fertilizers, and nanomaterial-enhanced fertilizers [19]. Current Nano-sized formulation of Nano fertilizers develops the solubility, dispersion of insoluble nutrients, bioavailability, and accessibility of definite delivery to decrease nutrient damages. Nanoscale based materials effort as the expertise for many proteins, photosynthetic pigments, coenzymes, purines, vitamins, activators for photosynthesis, and respiration systems of the plant. Mainly, the nanomaterial wasproduced via diverse engineered methods and then summarized the essential nutrients to grow target-specific plant uptake efficiency. On the basis of research, plant cell walls were functioned as the obstacle for self-defence with a pore size of 5 to 20 nm. Merely, the external agent with a lower diameter than the plant cells can go by the size exclusion limits (SELs) and advance embedded transport carriers of desired nutrients which are typically applied in soil or surface of the leaves. Similarly, other varied nanoparticles can be united to grow intracellular structures in cell walls to enter and enhance potential genetic properties. Consequently, Nano assisted fertilizers were presentedexceptional transport characteristics through plant tissues/cells with precise mobility over predictable water-soluble fertilizers. By using numerous ion channels through advanced feed mechanisms, issues like nutrients leaching, premature conversion, and soil fixation have been successfully alleviated. The operating mechanism of nanoparticles is malleable on both root entry and foliar entry. Consequently, Nano-assisted materials in Nano fertilizers perform a major role contrarily several abiotic stresses like drought [21], salinity [22], and metal stress [23]. Nano fertilizers have come to be an abundant another for soil management to decrease the over-application of conventional fertilizers. Further, the slow-release mechanism is providing the opportunity for practises according to evolution and ecological status. Besides, Nano fertilizers have revealed tremendous response to rapid plant growth and productivity but uptake, translocation, and accumulation of using nanoparticles is still not yet well distinct.

Application of Nano fertilizers

Macronutrient Nano fertilizers

Macronutrient Nano fertilizers are synthetically composed of one or more nutrients (e.g. N, P, K, S, Ca, and Mg) and essential in bulky amounts for plant growth development. As well, C, H, and O are existing in the atmosphere and simply integrated by crops. According to the literature, the key macronutrient (N, P, and K) were vanished 40%–70%, 80%–90%, and 50%–90% by spread over to the soil that affects a substantial loss of resources. Generally macronutrient fertilizer (P_2O_5+N_2+K_2O) consumption will be improved from 175.5 million tons (Mt) to 263 Mt in 2050 universally. Hence, due to squat efficiency and substantial application of conventional macronutrient (N and P) fertilizer, a vast amount of nutrients (N and P) were conveyed into surface and groundwater bodies that result into interrupt the aquatic ecosystems also threats human health]. Therefore, the extremely operative and ecologically friendly macronutrient Nano fertilizers are severely required to replace conventional macronutrient (N and P) fertilizer and to make certain sustainable food production. Thus, the expansion of macronutrient Nano fertilizer is a great priority in fertilizer to supply the definite amount of nutrients to the plants, decreasing transportation costs, as well as growing food production. Further, the macronutrient (N, P, and K) Nano fertilizer advances crop growth and harvests considerably and hence the rise of efficiency was linked to the conventional ones. The expenditure of macronutrient Nano fertilizer not only decreases the nutrient losses but also diminishes the contrary environmental impacts. These macronutrient Nano fertilizers

includes of one or more nutrients in summarized form with specific NPs. Numerous factors influence the efficiency of Nano fertilizers containing particle size, distribution, organic matter, uptake, soil texture, exposure route, soil pH, and accumulation of Nano fertilizers in crops. It was conveyed that the higher surface to volume ratio of NPs decreases the amount and increases the efficiency of macronutrient fertilizer in comparison to conventional fertilizers.

Limitation of Nano-fertilizer

The current development of consuming Nano fertilizer for accomplishing improved crop production is the indication of success. While the practice of Nano fertilizers is conclusively initial new attitudes to smooth and maintainable agriculture; their probable hazard to plants, soil organisms, and human health should also be cautiously measured before commercial application. The build-up of nanomaterial in the atmosphere and the food chain may cause a threat to human health. In accumulation, novel ecological and unpredicted health safety issues can bind the expenditure of nanotechnology in crop development. The use of nanostructures or nanoparticles as agrochemicals (fertilizers or pesticides) is scientifically being discovered before Nano fertilizers could be recycled in agriculture or farming for a general farm practice. Newly numerous studies described the long-term effect of bioaccumulation and exposure of NPs to the plants which may have an effect on the food chain [25, 26]. The uses of NPs as fertilizer also increase several safety (food safety, human and food security) and moral issues that need to be resolved previously commercial application. To report the safety concern detailed studies are essential to recognize the effect of nanoparticles within the human body once exposed through Nano food. Similarly, there is subsequently a essential to discover the possibility, risk assessment, hazard identification, and suitability of these novel smart Nano fertilizers [27]

FUTURE PROSPECTIVE

To accomplish the nutritional quality and security in the restricted land with limited resources, the perspective of the potential approach of Nano-biotechnology for user-friendly crop management will always be appreciated. Nano-trapped fertilizer occupied with biological agents (microorganisms, enzymes) can go durable profits for crop production. Consequently, the constant threat assessment and undesirable recognition of Nano-technological explanation in the agricultural sector may not be disregarded and can be taken extremely. The positive and negative aspects of nano-biofertilizers should be kept in mind so that there is a dire requires making potential efforts towards enhancing the futuristic researches to minimize the risk factors associated with NPs and bio-organic usage.

Only the laboratory-based experimentation could not benefit to the complete approval of the nano-biofertilizer technique in the accurate study and should be applied in the representative agricultural field. Though, an experimental design must be considered in a natural environment to give a detailed depiction of the environmental impact of NPs.

Government-based and scientific safety assessment should be measured during the research of nano-biofertilizers and leading the short-term organic/inorganic waste that require to be discovered and explained based on accurate natural conditions of the field.

The probable assessment and expansion founded on the influence of nanoparticles and Nano fertilizers should be considered for biotic and abiotic components of the ecosystem. Thus, another technique should be expressed to develop an eco-friendly and environmentally sustainable way for improving agricultural productivity.

The recognizing of the bio-magnification and biodegradability transmission effects of nano-biofertilizer on crops must be elaborate to attain a comprehensive knowledge of its toxicity.

Lastly, cost/benefit studies should be mandatory for the actual economic development of the use of nanofertilizers.

ACKNOWLEDGEMENTS

This work was supported by the Department of Biotechnology, Parul Institute of Applied Sciences, Vadodara-391760, Gujarat.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. S.K. Ghosh, T. Pal, (2007). Interparticle coupling effect on the surface plasmon resonance of gold nanoparticles: from theory to applications, Chem. Rev. 107; 4797–4862, https://doi.org/10.1021/cr0680282
2. C. Buzea, I.I. Pacheco, K. Robbie, (2007). Nanomaterials and nanoparticles: sources and toxicity, Biointerphases 2 MR17–MR71, https://doi.org/10.1116/1. 2815690

3. R. Taylor, S. Coulombe, T. Otanicar, P. Phelan, A. Gunawan, W. Lv, G. Rosengarten, R. Prasher, H. Tyagi,(2013). Small particles, big impacts: a review of the diverse applications of nanofluids, J. Appl. Phys. 113; 011301, https:// doi.org/10.1063/1.4754271
4. H.P.J. de Rouville, C. Kammerer, G. Rapenne, (2018). From the synthesis of nanovehicles to participation in the first nanocar race–view from the French team, Molecules 23; 612, https://doi.org /10.3390/ molecules23030612
5. M. Constantinescu, L. Dumitrache, D. Constantinescu, E.M. Anghel, V.T. Popa, A. Stoica, M. Olteanu, Latent heat Nano composite building materials, Eur. Polym. J. 46 (2010) 2247–2254, https://doi.org/ 10.1016/j.eurpolymj.2010.09.007
6. Z. Shami, A. Gharloghi, S.M. Amininasab, Multifunctional pH-switched superwetting copolymer nanotextile: surface engineered toward on-demand light oil–water separation on superhydrophilic–underwater low-adhesive superoleophobic nonwoven mesh, ACS Sustain. Chem. Eng. 7 (2019) 8917–8930, https:// doi.org/10.1021/acssuschemeng.9b00931
7. M. Faria, M. Bjornmalm, K.J. Thurecht, S.J. Kent, R.G. Parton, M. Kavallaris, A.P.R. Johnston, J.J. Gooding, S.R. Corrie, B.J. Boyd, P. Thordarson, A.K. Whittaker, M.M. Stevens, C.A. Prestidge, C.J.H. Porter, W.J. Parak, T.P. Davis, E.J. Crampin, F. Caruso, Minimum information reporting in bio–nano experimental literature, Nat. Nanotechnol. 13 (2018) 777–785, https://doi.org/10.1038/s41565-018- 0246-4
8. D.Ezzat , S.E. Amin, H.A. Shedeed, M.F. Tolba, Directed particle swarm optimization technique for delivering nano-robots to cancer cells, Proceedings of 13th International Conference on Computer Engineering and Systems (ICCES), 2018, 80–84, doi:10.1109/ICCES.2018.8639250.
9. Y. Genc, J. Taylor, G.H. Lyons, Y.L. Li, J. Cheong, M. Appelbee, K. Oldach, T. Sutton, Bread wheat with high salinity and sodicity tolerance, Front. Plant Sci. (2019) 1280, https://doi.org/10.3389/fpls.2019.
10. O. de Lange, E. Klavins, J. Nemhauser, Synthetic genetic circuits in crop plants, Curr. Opie. Biotechnol. 49 (2018) 16–22, https://doi.org/10.1016/j.copbio.2017. 07.003
11. K.K. Awasthi, P.J. John, A. Awasthi, K. Awasthi, Multi walled carbon nano tubes induced hepatotoxicity in Swiss albino mice, Micron 44 (2013) 359–364.
12. M. Yadi, E. Mostafavi, B. Saleh, S. Davaran, I. Aliyeva, R. Khalilov, M. Nikzamir, N. Nikzamir, A. Akbarzadeh, Y. Panahi, M. Milani, Current developments in green synthesis of metallic nanoparticles using plant extracts: a review, Artificial Cells Nanomed. Biotechnol. 46 (sup3) (2018) S336–S343
13. B. Kumar, K. Smita, A. Debut, L. Cumbal, Utilization of Persea americana (Avocado) oil for the synthesis of gold nanoparticles in sunlight and evaluation of antioxidant and photocatalytic activities, Environ. Nanotechnol. Monitor. Manage. 10 (2018) 231–237
14. J. Du, L.A. Lane, S. Nie, Stimuli-responsive nanoparticles for targeting the tumor microenvironment, J. Control. Release 219 (2015) 205–214.
15. A.A. El-Helaly, H.M. El-Bendary, A.S. Abdel-Wahab, M.A.K. El-Sheikh, S. Elnaga, The silica-nano particles treatment of squash foliage and survival and development of Spodoptera littoralis (Bosid.) larvae, J. EntomolZool. Stud. 4 (1) (2016) 175–180.
16. M. Kah, Nanopesticides and nanofertilizers: emerging contaminants or opportunities for risk mitigation?, Front Chem. 3 (2015) 64.
17. Madan, H.R., Sharma, S.C., Udayabhanu, Suresh, D., Vidya, Y.S., Nagabhushana, H., Rajanaik, H., Anantharaju, K.S., Prashantha, S.C., SadanandaMaiya, P., 2016. Facile green fabrication of nanostructure ZnO plates, bullets, flower, prismatic tip, closed pine cone: Their antibacterial, antioxidant, photoluminescent and photocatalytic properties. Spectrochim. Acta A 152, 404–416. https://doi.org/10.1016/j.saa.2015.07.067.
18. Duhan, J.S., Kumar, R., Kumar, N., Kaur, P., Nehra, K., Duhan, S., 2017. Nanotechnology: The new perspective in precision agriculture. Biotechnol. Rep. 15, 11–23. https://doi.org/10.1016/j.btre.2017.03.002
19. Wang, P., Lombi, E., Zhao, F.J., Kopittke, P.M., 2016. Nanotechnology: A new opportunity in plant sciences. Trends Plant Sci. 21 (8), 699–712. https://doi.org/10.1016/j.tplants.2016.04.005
20. Liu, R., Lal, R., 2015. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Sci. Total Environ. 514 (2015), 131–139. https://doi.org/10.1016/j.scitotenv.2015.01.10
21. Jaberzadeh, A., Moaveni, P., Tohidi Moghadam, H.R., Zahedi, H., 2013. Influence of bulk and nanoparticles titanium foliar application on some agronomic traits, seed gluten and starch contents of wheat subjected to water deficit stress. Bot. Horti Agrobot. Cluj-Napoca 41 (1), 201–207. https://doi.org/10.15835/nbha4119093
22. Siddiqui, M.H., Al-Whaibi, M.H., Faisal, M., Al Sahli, A.A., 2014. Nano-silicon dioxide mitigates the adverse effects of salt stress on Cucurbita pepo L. Environ. Toxicol. Chem. 33 (11), 2429–2437. https:// doi.org/10.1002/etc.2697
23. Tripathi, D.K., Singh, V.P., Prasad, S.M., Chauhan, D.K., Dubey, N.K., 2015. Silicon nanoparticles (SiNp) alleviate chromium (VI) phytotoxicity in Pisum sativum (L.) seedlings. Plant Physiol. Biochem. 96 (Vi), 189–198. https://doi.org/10.1016/j.plaphy.2015.07.026
24. Haghighi, M., Abolghasemi, R., da Silva, J.A.T., 2014. Low and high temperature stress affect the growth characteristics of tomato in hydroponic culture with Se and nano-Se amendment. Sci. Hort. 178, 231–240. https://doi.org/10.1016/j.scienta.2014.09.006
25. Bundschuh, M., Filser, J., Lüderwald, S., McKee, M.S., Metreveli, G., Schaumann, G.E., Schulz, R., Wagner, S., 2018. Nanoparticles in the environment: where do we come from, where do we go to? Environ. Sci. Eur. 30 (1), 1–17. https://doi.org/10.1186/s12302-018-0132-6

26. Tiede, K., Hanssen, S.F., Westerhoff, P., Fern, G.J., Hankin, S.M., Aitken, R.J., Chaudhry, Q., Boxall, A.B.A., 2016. How important is drinking water exposure for the risks of engineered nanoparticles to consumers? Nanotoxicology 10 (1), 102–110. https://doi.org/10.3109/17435390.2015.1022888
27. Rajput, V., Minkina, T., Sushkova, S., Behal, A., Maksimov, A., Blicharska, E., Ghazaryan, K., Movsesyan, H., Barsova, N., 2020. ZnO and CuO nanoparticles: a threat to soil organisms, plants, and human health. Environ. Geochem. Health 42 (1), 147–158. https://doi.org/10.1007/s10653-019-00317-3

CITATION OF THIS ARTICLE

N Jain, A Thakur, D Upadhyay, P Andhare, I Bhattacharya. Applications of Potassium Nanoparticles and their Evaluation as Growth Promoter in Wheat. Bull. Env. Pharmacol. Life Sci., Vol Spl Issue [3] 2022: 310-316