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An Analysis of Nanoparticle Effects on Plant Growth and Development

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Abstract*: Nanotechnology has developed into an exceptional instrument for the advancement of science and technology. In the agricultural sector, nanoparticles are employed. Many studies have been conducted to investigate the effects of nanoparticles on the growth and development of plants. Nanoparticles have both positive and negative effects on the growth and development of plants. Nanoparticles have the ability to regulate parasites and diseases, which in turn promotes the growth and development of plants, resulting in increased productivity and quality. Precision cultivation was facilitated by the site-specific and controlled delivery of inputs by nanoparticles. Researchers are striving to mitigate the adverse effects on the growth and development of plants. It is applicable at all stages, including processing, storage, and production, where it is used as inputs, such as nanofertilizers, nanoherbicides, and nanopesticides. Due to their diminutive size, these nanoparticles can effortlessly enter the plant through minute apertures. However, the public must embrace this nanotechnology. The public should be concerned about the safety of nanotechnology products. To ascertain the beneficial and detrimental impacts of nanoparticles on human health, plant growth and development, and animal health, additional research must be carried out.*

Keywords: Nanoparticles, Plant growth, Development, Environmental impact.

I. INTRODUCTION

Taniguchi introduced the term "nanotechnology" in 1974. The reactivity and potential biochemical activity of the nanoparticles (NPs) are enhanced by their high surface-to-volume ratio (Dubchak et al., 2010). For example, the particles may cover a 100 km2 area when 1 g of gold is converted to nanoscale. The melting point of gold nanoparticles (2.5 nanometer) is approximately 300°C, which is significantly lower than that of a gold slab (1064°C) (Buffat and Borel, 1976).Nanoparticles are particles that are less than 100 nanometer in size. Nanoparticles demonstrate enhanced properties that are contingent upon their size, orientation, and shape (Ram Prasad 2014). Nanoparticles detect maladies, protect plants, and promote plant growth, resulting in improved food quality and productivity. Additionally, nanoparticles facilitate the germination of seeds and the early growth of seedlings. They exhibit extraordinary properties in comparison to larger particles due to their diminutive size. Nanoparticles serve as a vector for the transmission of insecticides, herbicides, growth regulators, and fertilizers. The unsystematic application of large-sized fertilizer, herbicide, and pesticide particles can result in soil residues that have an impact on biodiversity. Crops should be supplied with the necessary quantity of inputs to surmount this requirement. The assimilation by plants is enhanced by the transformation of these inputs to nanoscale and their subsequent delivery to plants due to their diminutive size (Nethravathi et al., 2015). Nanotechnology's primary areas of focus include

- Nanofertilizers
- Nanopesticides
- Nanoherbicides
- Nanotechnology in hydroponics
- Nanotechnology in Organic Agriculture

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II. MATERIALS AND METHODS

Search strategy and selection criteria:

A comprehensive search was conducted using the keywords "nanotechnology" in Google Scholar, Google Web Browser, and Pub Meb Central. "nanoherbicides," "nanofertilizers," "nanopesticides," "nanotechnology in hydroponics," "nanotechnology in organic agriculture," and "positive and negative impacts of nanoparticles." The literature that was discovered in response to these searches was further screened for inclusion based on its contents and the year of publication. This review study primarily comprised scholarly articles that were published within the past year. Some papers that did not fall under the aforementioned category were excluded due to their significant data and relevance to the subject matter.

Table 1. Summary of negative impacts of nanoparticles on plant growth and development

S.No	Nanoparticles	Impact on Plants	Reference
1	Aluminium oxide	Stunt root growth in Corn, cucumber, soybean, carrot and cabbage	Michael Berger, 2007
2	zinc and zinc oxide	Inhibited seed germination and root growth of radish, rape, ryegrass, lettuce, corn and cucumber	Xing, 2007
3	Aluminium	Retarded root elongation of ryegrass and lettuce	Xing, 2007
4	Molybdenum	Root growth and elongation were arrested, root necrosis	Xing, 2007
5	Atrazine	Decrease of net photosynthesis and PSII maximum quantum yield, and increase of leaf lipid peroxidation, leading to shoot growth inhibition and the development of severe symptoms in Mustard	Halley 2015

III. RESULTS AND DISCUSSION

Positive Impact of Nanoparticles

In Spinacia oleracea, enzymatic activity is induced by nanoanatase TiO_2 0.25% (Yang et al., 2006). Lemna minor exhibited an increase in root length and biomass accumulation when exposed to aluminia nanoparticles at a concentration of 10 mg/L (Juhel et al., 2011). In corn, Alfalfa, and soybean, the growth of root and stem was substantially enhanced by serium oxide nanoparticles at concentrations of 500, 1000, 2000, and 4000 mg/L (Lopez-Moreno et al., 2010). In Vigna radiate, the biomass was increased by 50 ppm of iron oxide nanoparticles (Dhoke et al., 2010). In Triticum aestivum, the biomass was enhanced by 500mg/kg of copperoxide nanoparticles (Dimpka et al., 2012). The chlorophyll content of Triticum aestivum was elevated by 1000 mg/L of TiO_2 nanoparticles (80). In Cicer arietinum L., the dry weight of the shoot and root was substantially increased by 1.5 ppm zinccoxide nanoparticles (Burman et al., 2013). In Arachis hypogea, the growth of stems and roots and the yield were improved when zincoxide was applied at a concentration of 1000 ppm (Prasad et al., 2012).Soybean root growth was enhanced by zincoxide nanoparticles at a concentration of 500 mg/L (Lopez-Moreno et al., 2010).

Negative Impact of Nanoparticles

Despite the positive effects of nanoparticles, there are numerous negative effects that result in a decrease in plant growth and development, which ultimately leads to the plant's mortality.

Nanofertilizers

Products that are nanoscale in dimension and provide nutrients to crops are referred to as nanofertilizers. These nutrients can be i) encapsulated within nanomaterials, such as nanotubes or nanoporous materials, ii) coated with a thin protective polymer film, or iii) presented as emulsions or particulates (Luquen et al., 2016). The substitution of traditional fertilizer with nanofertilizers is advantageous because its application involves the controlled and gradual release of nutrients into the soil, thereby preventing water pollution (Naderi and Danesh Shahraki 2013; Moavenia nd Kheiri, 2011). In 2016, Luquen et al. reported that the germination and seedling growth of sunflower, common bean, and maize were improved, as well as the physiological activities of nitrogen metabolism and photosynthetic activity. Additionally, the mRNA expression and protein level were improved, and gene expression was positively impacted. These findings suggest that nanoparticles and nanotubes have the potential to increase crop yields. Liu and Lal synthesized hydroxyapatite ($Ca_5(PO_4)_3OH$) NPs that were 16 nm in size, which demonstrated a fertilizing effect on soybean. The application of nanofertilizer resulted in an increase in crop yield and a beneficial impact on environmental pollution. In comparison to P fertilizer, nanoparticles enhanced seed germination by 20% and growth rate by 33%. The findings suggested that soybean roots are capable of utilizing hydroxyapatite nanoparticles as an efficient source of phosphorus. The growth of 15-day lettuce seedlings was substantially enhanced by soil amended with metallic Copper nanoparticles, with a 40% and 91% increase in growth, respectively (Shah and Belozerov, 2009). Several studies that examined the characteristics of NPs also demonstrated that they have the ability to infiltrate plant cells and transport DNA and compounds within the cell (Ambrogio et al., 2013; Ghafariyan et al., 2013; Torney et al., 2007). The Iranian Nanotechnology Initiative Council (2014) reported that the nano-organic iron chelated fertilizers exhibited a high level of absorption, an increase in photosynthesis, and an expansion of the leaf surface size. The soil is significantly affected by nanofertilezers.

The frequency of fertilizer administration is reduced by nanofertilizers, which in turn reduces the toxicity of the soil (Naderi and Danesh-Shahraki, 2013). A gradual and sustained release of nitrogen over time was observed in the urea-modified hydroxyapatite nanoparticle-encapsulated Gliricidia sepium nanocomposite at three distinct pH values (Kottegoda, 2011). According to Manikandan et al. (2014), the addition of nanoporous zeolite to N fertilizer may serve as an alternative approach to improve the efficacy of N in crop production systems. Nanofertilizers play a significant role in sustainable agriculture as a result of their unique characteristics (El-Ramady, 2014). DeRosa (2010) reported that nutrients can be encapsulated by nanomaterials, administered as emulsions or NPs, or coated with a thin protective film in nanofertilizers.. The discharge of nutrients from the fertilizer capsule is regulated by nano and subnano composites (Liu et al., 2006).

Nanopesticides

Crop yields are restricted by pests. The overuse of pesticides in conventional methods of control results in a loss of biodiversity and an increase in costs. Pollution of the environment and water is a consequence of excessive use. The quantity of pesticides should be reduced in order to reduce the cost and protect the environment. It can be accomplished by increasing the efficacy and retention time of the pesticide. Pest control will be maintained for an extended period of time and will be kept below the threshold level due to the pesticide's extended persistence. Nanoencapsulation, a nanotechnology approach, enhances the efficacy of insecticides. A protective coating, or thin-walled capsule, envelops the nano-sized active pesticide ingredient.In the nano-encapsulation technique. Ali et al. (2014). This results in a reduction in environmental hazards, a decrease in pesticide input, and an increase in efficacy as a result of the "controlled release of the active ingredient." For instance, "Halloysite" (Clay nanotubes) have been created as cost-effective pesticide carriers. These will significantly reduce the quantity of pesticides necessary, as they have a longer release time and greater contact with plants. This will result in a significant reduction in pesticide costs with minimal environmental impact (Allen. 1994). Nano-silica has been tested for its potential to manage agricultural insect infestations. Physiosorptive is the mode of action of nano-silica. Through physical means, it results in the mortality of the insect by being ingested through the cuticular lipids of the insect (Ulrichs et al., 2005). Liu et al. (2006) have reported that the controlled release of pesticide can be effectively achieved by stacking porous hollow silica nanoparticles (PHSNs) with validamycin (a pesticide). Karate® ZEON, a broad-spectrum pesticide that is nanoencapsulated, has been introduced by Syngenta for the purpose of controlling insect pests in cotton, rice, legumes, and peanuts. The synthetic insecticide lambda-cyhalothrin, which is the active constituent of this product, is emitted upon contact with foliage. When exposed to an alkaline environment, such as the stomach of insects, another functional nano-insecticide known as "gutbuster" discharges its contents (Prasad et al., 2014).

Nanoherbicides

It is a technology that has been recently developed for the purpose of controlling weeds. Nano-herbicides are environmentally benign and effective in controlling weeds. Conventional herbicides are toxic to the soil biota and environment and will leave residues in the soil (Perez de Luque and Rubiales 2009). Additionally, certain herbicide residues may induce phytotoxic effects in subsequent crops. The selection of subsequent crops will be restricted by the use of conventional herbicides. Nano herbicides are nontoxic to the environment and soil, and they do not leave any residues (Chinnamuthu and Boopathi 2009). Nano-herbicides necessitate a reduced quantity to achieve effective vegetation control. Satapanajaru et al. (2008) have reported that Carboxy Methyl Cellulose nanoparticles can detoxify a herbicide atrazine by as much as 88%. The herbicide particles will combine with soil particles and control the vegetation that were resistant to conventional herbicides due to their limited size, specifically in nano dimensions. The primary objective of conventional herbicides is to eradicate the above-ground portion of plants. Nanoherbicides will penetrate the root system of vegetation and travel to regions that impede the glycolysis of food reserves in the root system. This results in the vegetation becoming malnourished and ultimately succumbing to death (Ali et al., 2014). Weeds that have been suppressed by conventional herbicides may reemerge. Conversely, nano herbicides will completely suppress the vegetation, including its rhizomes, which are incapable of regrowth. Sustainable agriculture is achieved through the reduction of herbicide use and the enhancement of efficiency, targeted delivery, and controlled use. It is imperative to detoxify weed residues, as the prolonged use of herbicides results in the accumulation of residues in the soil, which can cause harm to subsequent crops. The objective is to create a target-specific herbicide molecule that is encapsulated with a nanoparticle. This molecule is designed to bind to a specific receptor in the roots of target weeds, allowing it to enter the root system and be transported to the areas that inhibit the glycolysis of food reserves in the root system. This will result in the specific weed plant starving for sustenance and being slain (Chinnamuthu and Kokiladevi, 2007).

Nanotechnology in Hydroponics

Hydroponics is a field of agricultural science that is extensively used to cultivate edible crops and involves the cultivation of plants without soil (Seaman et al., 2014). Although hydroponics is a technology that is less well-known, it is used to cultivate a significant number of vegetables and fruits in supermarkets. The most frequently cultivated commodities in hydroponic systems include cucumbers, tomatoes, sweet peppers, melons, lettuce, strawberries, herbs, eggplant, and jalapenos. Hydroponics is also employed to cultivate biofuel and fodder crops. Giordani et al. (2012) reported that scientists have utilized hydroponics in nanotechnology by cultivating metal nanoparticles in living plants. Nutrient management is becoming increasingly significant and more effective in agricultural production in hydroponic than in soil-based production (Seaman et al., 2014). The potential for a nanophosphor-based electroluminescence illumination device to substantially reduce energy costs was reported by Witanachchi et al. in 2012. This illumination, which is based on nanotechnology, has the potential to reduce energy costs and promote photosynthesis in indoor environments.

Nanotechnology in Organic Agriculture

The use of nanotechnology in organic agriculture was condemned in the Position Paper on the Use of Nanotechnologies and Nanomaterials in Organic Agriculture by the International Federation of Organic Agriculture Movements. (IFOAM WORLD bank) Nevertheless, Nano Green Sciences, Inc. offers a nanopesticide that they assert is organic. Nanotechnology has been prohibited in the production of organic food in Canada. Canada's national organic regulations were amended to prohibit nanotechnology as a "Prohibited Substance or Method." (The Non-GMO and Organic Report)

Agriculture is currently confronted with the challenge of producing sustenance to meet the demands of an expanding population. The demand for agricultural products is also on the rise in conjunction with the growth of the population. In order to address this country's challenges, it is necessary to implement more efficient methods to increase productivity, feed an expanding population, and maintain productivity. Nanotechnology is at the forefront of the most recent technological advancements. It is pertinent to all stages, including inputs, processing, storage, and production. The controlled release and targeted delivery of inputs in nanotechnology will result in precision farming, as opposed to conventional methods. However, the public must embrace this nanotechnology. In order to ascertain the beneficial and detrimental effects of nanoparticles on human health, plant growth and development, and animal health, additional research must be conducted. The public should be concerned about the safety of nanotechnology products.

LITERATURE CITED

[1]. Ali, M.A., rehman, I., Iqbal, A., Din, S.U., Rao, A.Q., Ayesha, L., Samiullah, T.R., Azam, S. and Husnain, T. 2014. Nanotechnology: A new frontier in Agriculture.

[2]. Allen ,R. 1994. Agriculture during the industrial revolution. The economic history of Britain since. 1700(3): 96-123.

[3]. Ambrogio, M.W., Frasconi, M., Yilmaz, M.D. and Chen, X. 2013. New methods for improved characterization of silica nanoparticlebased drug delivery systems, Langmuir, 29: 15386-15393.

[4]. Burman, U., Saini, M. and Praveen-Kumar 2013., Effect of zinc oxide nanoparticles on growth and antioxidant system of chickpea seedlings, Toxicol Environ Chem, 95(4):605–612.

[5]. Chinnamuthu, C. and Boopathi, P.M. 2009. Nanotechnology and agroecosystem. Madras Agricultural Journal, 96(1- 6): 17-31.

[6]. Chinnamuthu, C. R. and Kokiladevi, E. 2007. Weed management through nanoherbicides. In: Application of nanotechnology in agriculture. C.R. Chinnamuthu, B. Chandrasekaran, and C. Ramasamy (Eds.) Tamil Nadu Agricultural University, Coimbatore, India

[7]. DeRosa, M.C., Monreal, C., Schnitzer, M., Walsh, R., and Sultan, Y 2010. Nanotechnology in fertilizers, Nat Nanotechnol, 5(2) : 91.

[8]. Dhoke, S.K., Mahajan, P., Kamble, R. and Khanna, A. 2013. Effect of nanoparticles suspension on the growth of mung (Vigna radiata) seedlings by foliar spray method, Nanotechnol Dev, 3(1).

[9]. Dimkpa, C.O., McLean, J.E., Latta, D.E., Manangón, E., Britt, D.W., Johnson, W.P., Boyanov, M.I. and Anderson, A.J. 2012. CuO and ZnO nanoparticles: phytotoxicity, metal speciation, and induction of oxidative stress in sand-grown wheat, J Nano Res, 14(9) :1–15.

[10]. El-Ramady, H.R., Integrated Nutrient Management and Postharvest of Crops, Sustainable Agri Rev, 13 (2014) 163–274.

[11]. Ghafariyan, M.H., Malakouti, M.J., Dadpour, M.R., Stroeve, P. and Mahmoudi, M. 2013. Effects of magnetite nanoparticles on soybean chlorophyll, Environ. Sci. Technol, 47 :10645–10652.

[12]. Giordani, T., Fabrizi, A. and Guidi, L., et al. 2012. Response of tomato plants exposed to treatment with nanoparticles. Environmental Quality. ~8:27–38.

[13]. Halley, 2015. Effects of nanopesticides on target and non- target plant species. Environmental Sciences.

[14]. IFOAM World Board . The use of Nanotechnologies and Nanomaterials in Organic Agriculture. Bonn, Germany: IFOAM World Board~ 2011. [Accessed April 19, 2014]

[15]. Iran Nanotechnology Initiative Council. First nano-organic iron chelated fertilizer invented in Iran [webpage on the Internet]. Tehran, Iran: Iran Nanotechnology Initiative Council; 2009. Availablefrom:http://www.iranreview.org/ content/Documents/Iranians_Researchers_ Produce_ Nano_Organic_Fertilizer.htm . Accessed April 11, 2014.

[16]. Luqueno, F.F. Valdez, F.L., Fernanda, M., Rodríguez, V., Pariona,N., Luís, J., López, H., Ortíz, I.J., Baltazar, J.L., Sánchez, M.C.V., Zapata R.E., and Gallegos, J.A.A. 2016. Effects of Nanofertilizers on Plant Growth and Development, and Their Interrelationship with the Environment. Agriculture and Food science. 211-224.

[17]. Manikandan, A. and Subramanian, K.S. 2014. Fabrication and characterisation of nanoporous zeolite based N fertilizer, Afr J Agric Res, 9(2) : 276–284.

[18]. Michael Berger. 2007. Nanoparticles could have negative effect on plant growth.

[19]. Moaveni, P. and Kheiri, T. 2011 . 2nd International Conference on Agricultural and Animal Science; November 25–27, 2011; Maldives. Singapore: IACSIT Press 22:160–163.

[20]. Naderi, M.R. and Danesh-Shahraki, A. 2013. Nanofertilizers and their roles in sustainable agriculture, Int J Agri Crop Sci, 5(19) : 2229–2232.

[21]. Nethravathi, M., Divya, K.H., Prashanth Kumar, H.P., Saranya, D. and Shashidara, K.S. 2015. Characterisation and Analysis of Nanosized Fertilizers and their Effect on Cereal plants. International Journal of Che Tech Res., 8 (5): 148-152.

[22]. Prasad, T.N.V.K.V., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V., Reddy, K.R., Sreeprasad, T.S.P., Sajanlal, R. and Pradeep, T. 2012. Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut, J Plant Nutr, 35(6) : 905–927.

[23]. Prasad, R., Kumar, V. and Prasad, K.S.. 2014. Nanotechnology in sustainable agriculture: Present concerns and future aspects. African Journal of Biotechnology, 13(6): 705-713.

[24]. Pérez de Luque, A. and Rubiales, D. 2009. Nanotechnology for parasitic plant control. Pest management science, 65(5): 540-545.

[25]. Ram Prasad, 2014. Synthesis of silver nanoparticles in photosynthetic plants. Journal of nanoparticles.

[26]. Satapanajaru, T., Anurakpongsatorn, P., Pengthamkeerati,

[27]. P. and Boparai, H. 2008. Remediation of atrazine- contaminated soil and water by nano zerovalent iron. Water, air, and soil pollution, 192(1-4): 349-359.

[28]. Schwabe, F., Schulin, R., Limbach, L.K., Stark, W., Bürge,

[29]. D. and Nowack B. 2013. Influence of two types of organic matteron interaction of CeO2 nanoparticles with plants in hydroponic culture. Chemosphere. 91(4):512– 520.

[30]. Seaman, C. and Bricklebank, N. 2014. Soil-free farming. Chemistry and Industry Magazine. 2011. [Accessed April 19]. Pp.19-21.

[31]. Seaman, C. and Bricklebank, N. Soil-free Farming, Chemistry and Engineering Magazine. 2011. [Accessed April 19, 2014]. p. 6

[32]. Shah, V. and Belozerova, I. 2009. Influence of metal nanoparticles on the soil microbial community and germination of lettuce seeds, Water Air Soil Pollut, 197, 143–148.