Science of the Total Environment 568 (2016) 470–479

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Lessons learned: Are engineered nanomaterials toxic to terrestrial plants?

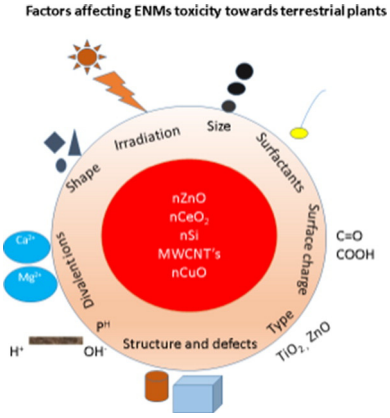
P. Venkata Laxma Reddy [a,c], J.A. Hernandez-Viezcas [b,c], J.R. Peralta-Videa [a,b,c], J.L. Gardea-Torresdey [a,b,c,*]

[a] Environmental Science and Engineering PhD Program, The University of Texas at El Paso, 500 West Univ. Ave., El Paso, TX 79968, USA
[b] Chemistry Department, The University of Texas at El Paso, 500 West Univ. Ave., El Paso, TX 79968, USA
[c] University of California Center for Environmental Implications of Nanotechnology (UC CEIN), The University of Texas at El Paso, 500 West Univ. Ave., El Paso, TX 79968, USA

HIGHLIGHTS

- Multi biotic and abiotic factors affect the interaction of ENMs with plants.
- ENM exposure at concentrations <50 mg/kg are usually beneficial to plants.
- The effects of ENMs on color, texture, and taste of vegetables are not known.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 30 March 2016
Received in revised form 7 June 2016
Accepted 7 June 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Nanoparticle-plant interactions
Nanotoxicity
Fate
Transport
Transformation

ABSTRACT

The expansion of nanotechnology and its ubiquitous applications has fostered unavoidable interaction between engineered nanomaterials (ENMs) and plants. Recent research has shown ambiguous results with regard to the impact of ENMs in plants. On one hand, there are reports that show hazardous effects, while on the other hand, some reports highlight positive effects. This uncertainty whether the ENMs are primarily hazardous or whether they have a potential for propitious impact on plants, has raised questions in the scientific community. In this review, we tried to demystify this ambiguity by citing various exposure studies of different ENMs (nano-Ag, nano-Au, nano-Si, nano-CeO_2, nano-TiO_2, nano-CuO, nano-ZnO, and CNTs, among others) and their effects on various groups of plant families. After scrutinizing the most recent literature, it seems that the divergence in the research results may be possibly attributed to multiple factors such as ENM properties, plant species, soil dynamics, and soil microbial community. The analysis of the literature also suggests that there is a knowledge gap on the effects of ENMs towards changes in color, texture, shape, and nutritional aspects on ENM exposed plants.

* Corresponding author at: Environmental Science and Engineering PhD Program, The University of Texas at El Paso, 500 West Univ. Ave., El Paso, TX 79968, USA.
E-mail address: jgardea@utep.edu (J.L. Gardea-Torresdey).

http://dx.doi.org/10.1016/j.scitotenv.2016.06.042
0048-9697/

Contents

1. Introduction

Nanotechnology industry is progressing and it has rapidly emerged into a technological sensation in the last two decades. This industry is operating in numerous fields of science and is constantly expanding its applications (Barkalina et al., 2014; Ditta et al., 2015). Engineered nanomaterials (ENMs) are the building blocks of nanotechnology. Their unique properties and new characteristics, compared to their bulk counterparts, are the reasons behind their industrial and scientific success. Although nanotechnology is already a billion dollar industry globally, extensive ongoing research proves that this technology is still in the exploration stage and it has been projected to grow further (Shapira and Youtie, 2015). To meet the ever increasing industrial demand, NMs are manufactured expansively. This massive and unrestricted use of ENMs in recent years has led researchers to ponder the issues, questions, challenges, and consequences of their environmental impact (Gottschalk et al., 2015; Tolaymat et al., 2015). Among the diverse studies that are been carried out, the impact of ENMs in ecosystems and their involvement in the food chain has conveyed some alarming discoveries. For the most part, experimental studies have proven that ENMs can pose undesirable effects to the food chain producers. There are some excellent reviews which have thoroughly emphasized these findings (Rico et al., 2011; Gardea-Torresdey et al., 2014). The most compelling evidence is primarily attributed to the tendency of the plants to uptake ENMs through their roots, followed by translocation, biotransformation, and perturbation of physiological functions (Li et al., 2015). Impairment in physiological functions can affect seed germination, seedling growth, increase reactive oxygen species (ROS) generation, disrupt cell walls, and modify biomolecules such as: proteins, carbohydrates, lipids, pigments, and hormones (Rico et al., 2014; Majumdar et al., 2014; Siddiqui and Al-Whaibi, 2014). Conversely, reports show the positive effects of ENMs as they are proven to act as pesticides and fertilizers. There are some excellent reviews on the beneficial effects of ENMs on plant growth as well (Adhikari et al., 2010; Gopal et al., 2012; Tiwari et al., 2014). Overall, the impact of ENMs on plants is still debatable, and there is no conclusive explanation pertaining to this situation. In this review we explore various factors that have probably determined both the positive and negative responses (Fig. 1). We include a brief discussion on two important facets of the ENM-plant studies: The interactions of ENMs with environmental components (soil and water) prior to their interaction with plants and the corresponding responses as an outcome of ENMs exposure. Accordingly, it is expected that this review will be helpful to expand our knowledge about implications and impact of ENMs in terrestrial plants.

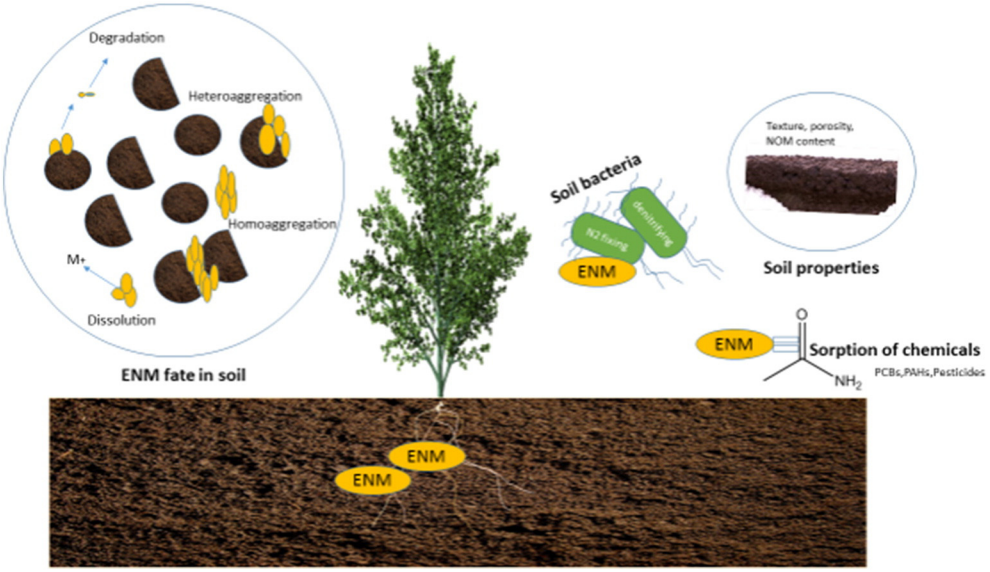


Fig. 1. Biotic and abiotic factors contributing for ENMs toxicity towards plants.