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Smart Fertilizers vs. Nano-fertilizers: A Pictorial Overview

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DUE to the rapid population growth, global food production should be increased to meet this global demand. Agriculture is considered the main dominant channel of food supply and any approach that support the crop productivity is urgent. These agro-practices may include using the high-yield varieties, improving rational irrigation and fertilization. It is noticed that, using of chemical or mineral fertilizers in agricultural production dramatically increased global food production. Several negative impacts have been recorded worldwide on the environment, which resulted from leaching of nutrients into groundwater, beside the low efficiency of applied fertilizers. Applying of nanofertilizers, is a promising approach, and an effective technology, which can increase sustainability and efficiency of agro-production of cultivated crops because of their nano-size properties, their high nutrient use efficiency, their slow release of nutrients, and thereby low required applied dose of fertilizer. Smart fertilizer means the control dose and time of applied fertilizers using the smart agro-technological and advanced tools such as global positioning systems, and remote sensing. These tools are able to maximize crop yield and minimize agro-chemical inputs by precise monitoring of the environment. Therefore, this work is a comparison between smart fertilizer and nanofertilizer, and to answer the main question: are the bio-nanofertilizers considered emerging precision agriculture strategy? This is also a call by Environment, Biodiversity and Soil Security (EBSS) for receiving articles on smart fertilizer, under many related topics such as different applications of smart fertilizers in smart agriculture, their challenges, their obstacles and the novel solutions in this concern.

Keywords: Smart farming, Precision farming, Bio-nanofertilizer, GIS, GPS, Fertigation.

1. Introduction

Several challenges face the humanity nowadays to achieve sustainable development goals such as addressing climate changes, achieving global food security, and halting the environmental degradation of natural resources (Aryal et al. 2021). These previous challenges have close link to the agriculture sector, which has an accelerated growth in its production due to the extension of cultivated soils, and the increase in technology alternatives for

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enhancing the agro-productivity due to the Green Revolution (FAO 2019). Agriculture sector globally has the ability to produces about 23.7 million tons of food per day, which contributes in greenhouse gas emissions more than 21% (Panuccio et al. 2022). The increase in agro-production is controlled by many environmental factors, which affect negatively soil, water, and air resources (Panuccio et al. 2022). On the other hand, a very rapid increase in global population was noticed, which is predicted to be near to 10 billion in 2050 (United Nations 2019). Therefore, there is a dire need to develop the efficiency of many agricultural practices to mitigate global hunger and poverty (Zulfiqar et al. 2019). Thus, many agricultural practices should be improved to increase the agro-productivity such as the use of hybrid crop varieties, sustainable agro-chemicals, as well as improving irrigation and fertilization practices (Ndaba et al. 2022).

Using of fertilizers is an important agro-management practice to increase crop productivity and improve soil fertility through enhancing the supply of fertilizers and soil amendments (Aryal et al. 2021). Extensive fertilization using traditional chemical fertilizers may be lost from the top soil by leaching to reach water bodies, accordingly these practices lead to poor nutrient use, whereas controlled-release fertilizers could be more advantageous compared to conventional fertilizers (Vejan et al. 2021). The global demand for mineral fertilizers (including NPK) was estimated by 185.06 million tons in 2016, and is predicted to increase up to 200.92million tons in 2022 (Wang et al. 2022). Several studies have been recently published on controlling the release of fertilizers or so-called nano-fertilizers and their prospective in increasing crop production (e.g., Shams and Abbas, 2019; Madzokere et al. 2021; Beig et al. 2022; Bhardwaj et al. 2022; Dhlamini et al. 2022; Jakhar et al. 2022; Wang et al. 2022), but the impacts of nano-fertilizers on environmental compatibility, crop quality, and non-targeted organisms need further research (Vejan et al. 2021). After the revolution of nanotechnology and using of nanofertilizers, and smart fertilizers, which can be used in smart agriculture is a promising. Therefore, this work involved the smart fertilizer and its comparison to nanofertilizer. It is also a photographic call for submitting articles by EBSS on smart agriculture and smart fertilizer to answer the main question in this work: what is the main difference between smart fertilizer and nanofertilizer?

2. What is the nanofertilizer?

Nanotechnology is the science that deals with any materials or particles in the size of nano-level (1 – 100 nm) in any of its dimensions. Nanotechnology has a wonderful list of applications in the agriculture sector (Fig. 1). Nano-fertilizers are a kind of fertilizer, in which their nanoparticles are submicroscopic sizes, having the ability to be encapsulated by the nutrients, having a large surface area to volume ratio, and having the higher mobility of nutrients compared to traditional fertilizers (Jakhar et al. 2022). Nano-fertilizers are considered deliverable agents or '*smart system of nutrients*' due to their properties that support their delivering nutrients to cultivated plants (Table 1). Nanofertilizers can increase nutrient efficiency, improve plant nutrition, and also improve soil fertility (Toksha et al. 2021). The efficacy of applied nanofertilizers depends mainly on the agroecosystem conditions including different physicochemical properties of soils, moisture, and other agro-ecological conditions (Jakhar et al. 2022).

The technology of nanofertilizers has a great role in developing different kinds of fertilizers such as using the hybrid nano-composite of nanofertilizer from Cu, Fe and Zn (Rahman et al. 2021), or chitosan-based nano-fertilizers (Jakhar et al. 2022; Prajapati et al. 2022), or different nano-enabled fertilizers of zinc oxide nanoparticles (ZnO-NPs), iron oxide nanoparticles (FeO-NPs) and magnesium oxide nanoparticles (MgO-NPs) (Khalid et al. 2022), ZnO-NPs coated urea granules (Umar et al. 2022), nano-hydroxyapatite as P-nanofertilizer (Sajadinia et al. 2021), lignin-clay nanohybrid as bio-based slow-release fertilizers (Zhang et al. 2022), green synthesized fertilizer of zinc nanostructure (Zn NS) (Bahmanzadegan et al. 2022), combined applied biochar and ZnO nanofertilizer (Sheikhnazari et al. 2022), nano-rock phosphate as a nano-P-fertilizer (Yasmeen et al. 2022), and Fe_3O_4-urea nanocomposites as N-fertilizer (Guha et al. 2022).

Table 1. List of some studies on applied nanofertilizers on cultivated plants and their impacts.

Cultivated plant	Applied nanofertilizer	Applied dose	Plant studied parameter	Refs.
Maize (*Zea mays* L.)	ZnO as nano-fertilizer	Soil (40-160 mg kg^{-1}) Foliar (10 – 40 mg L^{-1})	Plant growth increased by 59%, photosynthetic pigments 48%, antioxidant activity by 52.9%	[1]
Rosemary (*Rosmarinus officinalis* L.)	Hydroxyapatite nanofertilizer	Nanofertilizer at 0.5 and 1.0 g L^{-1}	Highest values: stem diameter, fiber thickness, phloem tissue thickness, xylem tissue thickness using nanofertilizer	[2]
Medicinal plants (*Caesalpinia bonducella*)	Nano-ZnO, FeO, and MgO fertilizers	Doses from 10 – 40 ppm for nano- Fe-/Mg-fertilizers and 25 – 100 ppm nano Zn-fertilizers	Increased nutrient, growth, and chlorophyll contents of plants at applied dose of n-fertilizers 40 ppm (Mg and Fe); 100 ppm (Zn)	[3]
Persian thyme (*Zataria multiflora* Boiss)	Green fertilizer Zn-nano-structure (Zn NS)	Foliar Zn-NS fertilizer at 100, and 300 mg L^{-1}	The highest dose improved plant's essential oil constituents, antioxidant activity, total phenolic and its compounds, flavonoid, carotenoid, chlorophyll	[4]
Rice (*Oryza sativa* L.)	Fe_3O_4-urea nanocomposite	Fe_3O_4-NP: urea at 1:1, 1:2, and 1:3 ratio	Increased crop yield when 50% N was supplemented in Fe_3O_4 NPs: urea (1:3) ratio and the rest in form of ammonium nitrate	[5]
Cluster bean (*Cyamopsis tetragonoloba*)	Nano Hydroxy-apatite fertilizer	Not available	Nano-fertilizer enhanced the plant growth and its yield	[6]
Cluster bean (*Cyamopsis tetragonoloba*)	ZnO nanofertilizer	Foliar spray ZnO nano-fertilizer at 20 mg L^{-1}	ZnO nanofertilizer improved plants tolerant against pathogens and its growth and yield of cluster beans	[7]
Cucumber (*Cucumis sativus* L.)	Nano-selenium	Foliar nano-Se (25 mg L^{-1})	Foliar nano-Se promoted bio-stimulant increasing the growth under salinity and heat stress	[8]
Maize (Zea mays)	Nano ZnO	Foliar nano-ZnO (0-15 mg L-1)	This spray significantly raised P and Zn status in maize shoots and grains, especially with increasing the dose of application. Accordingly, this spray boosted maize growth, yield and yield components and its efficiency exceeded both Zn-EDTA and ZnSO4.	[9]
Wheat (*Triticum aestivum* L.)	Nano ZnO	Foliar nano ZnO (0-80 mg L-1)	Wheat growth was enhanced with the application of nano-ZnO up to 50 mg L−1 under salinity stress conditions while decreased thereafter. Also, the nano Zn-spray decreased significantly the enzymatic and non-enzymatic activities of plants	[10]

List of refs. [1] Azam et al. (2022), [2] Elsayed et al. (2022), [3] Bahmanzadegan et al. (2022), [4] Bahmanzadegan et al. (2022), [5] Guha et al. (2022), [6] Shylaja et al. (2022), [7] Rexlin et al. (2022), [8] Shalaby et al. (2021), [9] Abbas et al. (2021), [10] Lalarukh et al. (2022).

The main target of nanofertilizers application is the regulation of nutrient release rate with high nutrient uptake efficiency for satisfying the needs of crop growth and productivity. As mentioned above, there are many different forms of nanofertilizers, that could be fabricated using many natural and synthetic materials. Nano fabrication fertilizers could be classified into these categories:

(1) Nano-supported-fertilizers or nanoscale additives (bulk products with nanoscale additives): kind of fertilizers in which nanostructured materials could be applied as additives to regulate release of fertilizers (e.g., entrapment nanofertilizer, and adsorption nanofertilizer), nutrients incorporated into nanocarriers,

(2) Nanosized fertilizers or nanoscale fertilizer or synthesized nanoparticles, which refer to fertilizers made in nanoscale, and

(3) Nano-wrapped fertilizers or nanoscale coating or host materials (product coated with nano-polymer or loaded with nanoparticles, which apply nanomaterial wraps or coatings to contain regular size fertilizers (Calabi-Floody et al. 2018; Shao et al. 2022).

3. Fertigation system

Simply fertigation is defined as a system or process that combines both fertilization (the first half of the word) and irrigation (the second half of the word). Fertigation has many benefits including saving costs via using reduced fertilizer doses, tackling soil erosion, eliminating pollution with used agrochemicals, decreasing fertilizer leakage, controlling administered rates, optimizing water consumption, and promoting rapid root growth. The fertigation through drip irrigation can simultaneously address both water and fertilizer applications, leading to considerable increases in crop productivity and enhancement in both nutrient and water use efficiency (Surendran and Chandran 2022). Therefore, many published studies confirmed the regulation of the quantity of water and nutrients based on crop requirements under drip fertigation (e.g., Abubakar et al. 2022; Nayebloie et al. 2022; Surendran and Chandran 2022).

The fertigation system uses a variety of fertilizer injectors, from the conventional simple tank to the automatic injector. The conventional closed tank and the injector pump are the two primary methods for dispensing chemicals through irrigation systems. Most injector pumps are either piston or Venturi pumps. While the piston pumps can be installed either in-line or on a bypass line, the closed tanks are always installed on a bypass line. The Venturi tube serves as the foundation for the fertilizer injector. Between the injector's input and output, there must be a pressure difference. Piston pumps can be mounted directly on the supply line rather than the bypass line and are powered by the system's water pressure. dialed-in pumps (Taha 2022). To help lower the reservoir level and/or to maintain the biological minimum flow required downstream, gated conduits make sure water is moved from the reservoir downstream. Gated conduits frequently act as water intakes for some customers, primarily for irrigation, for minor dams and reservoirs (Tanchev 2014). More irrigation water may be saved, and fertilizer application efficiency has been improved. Thanks to the development of equipment and management instructions for surge flow irrigation (Okasha et al. 2022).

4. Smart fertilizer vs. nano-fertilizer

Precision or smart farming is a kind of agriculture, in which bioinformatics could be used in different sectors in agriculture. In simple words, how to deliver the water (as a smart irrigation), or fertilizers (smart fertilizer), or any other agro-practice in a certain time. There are several sensors, which already have been used in many agro-activities especially the monitoring of soil, water, cultivated plants. Nanotechnology has great applications in many advanced technological areas including information technology (IT), biomedical engineering, smart farming, and food sciences (Shao et al. 2022). Using of nanotechnology in smart farming has many benefits, in which many nano-sensors could be used for monitoring soil conditions, monitoring plant pathogen and pesticides detection, monitoring plant-specific treatments through robotic, bio-sensors in smart machines for precise weed control, and nanoparticles-based smart delivery system for nutrients, growth regulators, nano-pesticides, nano-herbicides (Calabi-Floody et al. 2018). For smart agriculture, agrochemicals prepared in different nano-formulations have been applied due to their controlling and stimulation-regulated release rate, enhanced compatibility and increased solubility, time- or location-specific targeting, long-term stability and duration (Shao et al. 2022).

What is the difference between smart fertilizer and nanofertilizer? In brief, nanofertilizer is a kind of smart fertilizers, which has the same benefits of smart fertilizers in delivering nutrients as a tailoring agent or an agro-nanotechnology. Many published articles confirmed the role of agro-nanotechnologies, which have been proposed and substantially examined over the last two decades, with tens of reviews published from various perspectives (Shao et al. 2022). These studies included smart fertilizers as a strategy for sustainable agriculture (Calabi-Floody et al. 2018), smart nanomaterials and nanocomposites for advanced agrochemical activities (Kumar et al. 2021), nanotechnology-based controlled release of sustainable fertilizers (Beig et al. 2022), using of bio-nanoparticles as fertilizers in smart farming (Ndaba et al. 2022), functional nanomaterials (NMs) for sustainable and smart agricultural chemical technologies (Shao et al. 2022), and smart nano-biosensors for sustainable agriculture and environmental applications (Ramachandran et al. 2022).

Agriculture sector includes several farms such as crop farming, floriculture, viticulture, aquaculture, microalgae farming and livestock, which several farms already have been implemented to be smart farming through application of artificial intelligence (AI) technology, and Internet of Things (IoT) to improve their productivity and their quality (Lim et al. 2022). A general comparison between smart fertilizer and nanofertilizer can be noticed in **Fig. (2**), whereas many photos are listed in **Fig. (3**) offer more information about the smart fertilizer in the system of fertigation or smart irrigation as well. It is worth to mention that, targeting a not selected plant and/or microbe species with possible adverse effect is a key issue emerging that put a loophole of criticism for these smart nano-agrochemicals, as reported by Kumar et al. (2021). Smart fertilizer includes nanofertilizer, so smart fertilizer is wider concept that includes the nanofertilizer in particular.

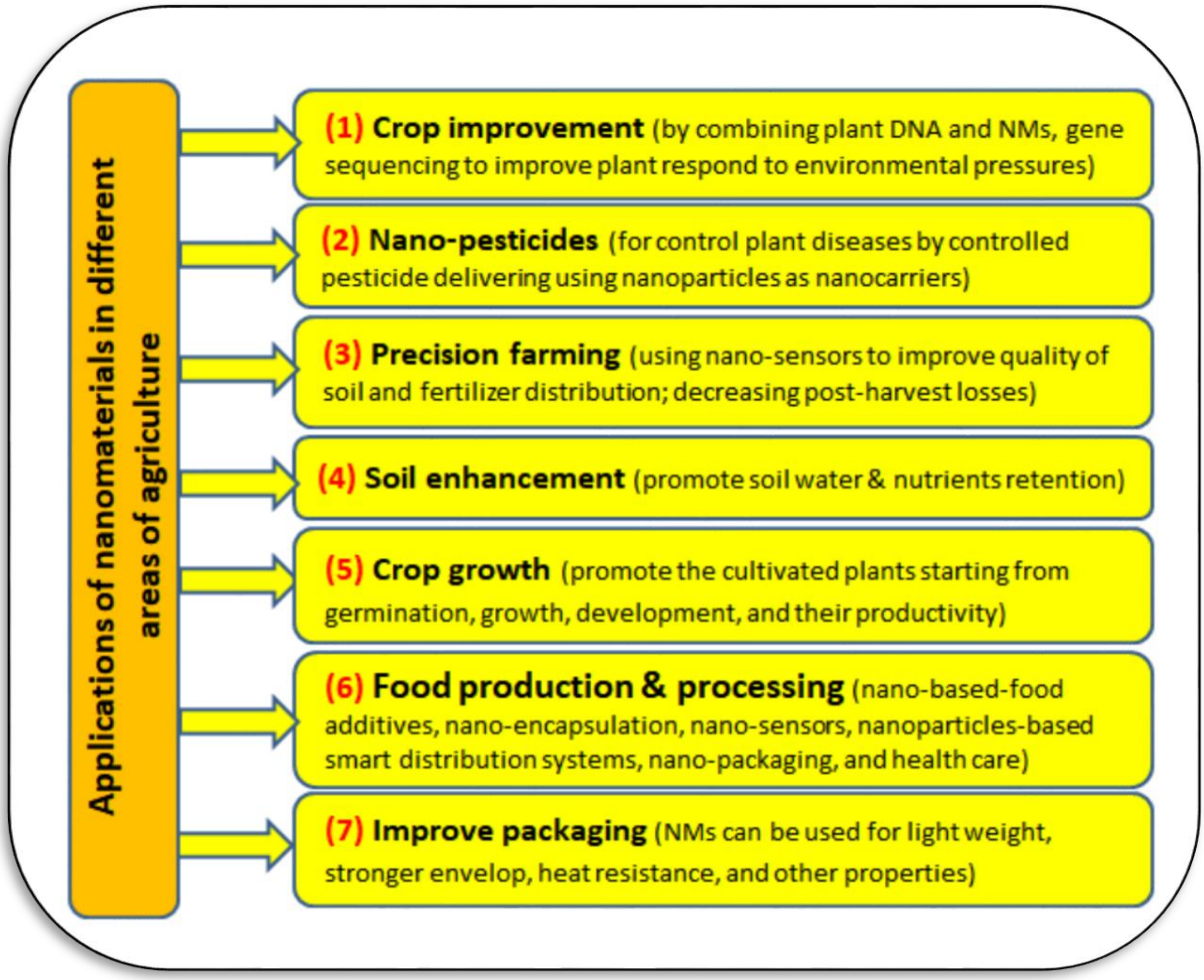

Fig. 1. The main applications of nanotechnology in the agriculture and food sectors.

Fig. 2. A general comparison between smart fertilizer and nanofertilizer.

Automatic fertigation system by using three tanks A, B and C (left photo), and control valve. Netafim irrigation control valve in ground (right photo)

Meteorological weather station by solar energy, as one of the components that complements smart irrigation system (left) and part of the fertigation in the field (right photo)

Measurement of the conductivity and temperature of soil which is used in smart irrigation scheduling (left photo), saving irrigation water by using plastic mulch which reduces evapotranspiration

Smart irrigation and fertilizer in a field cultiavted with potato crop using some sensors

Motoring automatic drip irrigation system for large scale powered by solar energy (left photo), motoring station of soil moisture content and soil temperature at different depth by sensors at plant seedling stage

The unit of smart fertilizer in the fertigation system by using sensors

Fertilizer tanks and their control units (left photo), control board, check valves, solenoid valves and pressure gauge for smart fertigation (right photo)

Photos for hydroponic systems including lettuce and leafy vegetables

Fig. 3. Some photos from the smart irrigation system, which includes different components.

5. A call for photographical articles

Environment, Biodiversity and Soil Security (EBSS) journal already planned this year, for more calls including more new hot topics. EBSS already started publication through a call for smart farming for developing sustainable agriculture (Fawzy and El-Ramady 2022), smart irrigation (Fawzy et al. 2022c), then move to a call on Soil-Water-Plant-Human Nexus (Brevik et al. 2022). At the same time, more calls for submission of photographic review or mini-review such as Global Soil Science Education (Koriem et al. 2022), Management of Salt-Affected Soils (El-Ramady et al. 2022a), Soil-Water-Plant-Human Nexus (Brevik et al. 2022), Grafting of Vegetable Crops (Bayoumi et al. 2022), Sustainable Applications of Mushrooms in Soil Science (Fawzy et al. 2022b), and on Nano-Farming of Vegetables (Fawzy et al. 2022a). This is a new call for more publications on smart fertilizer under the umbrella of smart agriculture especially using the photographic reviews or mini-reviews. More submission of articles is most welcome. We have more different photographic call for the Egyptian Journal of Soil Science like a call on Sustainable Applications of Mushrooms (Fawzy et al. 2022d), and on Soil and Humans (El-Ramady et al. 2022b).

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