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Application of nano organic materials for sustainable agro-productivity, food security and environment: A review article

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Abstract Global agricultural production suffers from many challenges and problems, including environmental pollution, soil degradation, climate change, depletion of natural resources and others. Nanotechnology represents one of the most important solutions that will help to overcome these challenges. Nanotechnology is helping to better manage organic farming using natural products constructing to be nano-fertilizers, nano-pesticides, biosensors, nano-diagnostics, nano-growth stimulators, and others. Organic nanos are formed through biological methods, not physical or chemical, as they do not follow the standards of organic farming. Hence, the green synthesis of nanomaterials or the so-called nano-methods is one of the requirements and components of organic farming. The use of plant parts such as stems, roots, leaves, flowers, fruits and various beneficial microbes such as bacteria, fungi and algae are essential for nanoparticle synthesis or called green synthesis. In addition, organic nano-elements help agricultural production to make optimal use of natural resources in a more sustainable way and reduce agricultural toxic residues. Therefore, this review is highlighted the new ways and approached for using nanomaterials in organic agriculture for sustainable agricultural productivity, food security and climate change.

Keywords: Nano organic fertilizer, Nano pesticides, Nano plant growth stimulators, Green synthesis

Introduction

There are important challenges nowadays in the field of agriculture and that the use of modern technologies is what can help in meeting the need for qualitative and quantitative food. At the same time, the use of chemical and genetic pesticides and fertilizers. It causes damage to the environment and caused disruption to the ecosystem (Fraley *et al.,* 1983). In recent decades, solutions to these challenges have been the use of organic farming. Given the health benefits of organically grown food and food safety, it has led to the start of the second green revolution. Organic food is produced without the use of chemical fertilizers, pesticides, chemically synthesized diseases or the use of

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genetically modified organisms, growth hormones and antibiotics (Das *et al.,* 2020). The word "organic" in his published book "Look at the Earth" in 1940. The name of organic agriculture has also been given to the environmental production management system and preservation, biogeochemical cycles, soil vitality, sustainability, food quality and protection (Nourthbourne, 2003). Organic farms are also characterized by increased environmental protection and tolerance of changes in the external environment (Eva-Marie Meemken and Qaim, 2018).

Nanomaterials have changed the methods of modern agriculture and helped create solutions to the challenges of conventional farming as well as improving the applications of organic farming. Nanotechnology is the technology associated with materials, processes and systems operating at the nanoscale. The nanoparticles found in sizes smaller than 100 nanometers cause drastic changes to the material and chemical properties. Nanomaterials include nanoparticles, nanotubes, and nanostructures. Nanomaterials can be created in three ways including biological, physical and chemical (Vinod and Jelinek, 2019). Biological methods or that so-called green synthesis of nanoparticles and applications are considered safe in crops for the long-term sustainability of agriculture and the environment. Diseases and pests can also be identified at an early stage of infection using nano-sensors, they are monitored and improved efficiency . Nanoparticles have a low surface area in relation to volume, which leads to an increase in the efficiency of high absorption of nutrients and water and helps in the protection and quality of food by using nano-sensors by improving processing and transportation, which is reflected in a decrease in the loss of the crop after harvest (Thirugnanasambandan, 2021), and and its use in gene transfer as a smart delivery system (Peters *et al.,* 2016) . The agricultural sector also produces large quantities of agricultural waste, which is recycled and used to produce nanomaterials.

Nanotechnology and sustainable agricultural development

Many agricultural sectors suffer from problems such as climate change, sustainable use of natural resources, environmental pollution and other environmental issues, including runoff and accumulation pesticides, fungicides and chemical fertilizers (Arodudu *et al.,* 2017). Nanoparticles play a new approach to sustainable agricultural productivity directly and indirectly for improving productivity through nutrient management, fertilization, water quality, pesticides and pesticides for sustainable development of agriculture (Mukhopadhyay, 2014). There are many technological properties of nanoparticles methods, including atomic force scanning electron microscopy

(AFM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Dynamic light scattering (DLS), Brunauer–Emmett–Teller (BET), X-ray diffractometer (XRD) and UV-vis spectrophotometer (Madhumitha *et al.*, 2016). Nanoparticles have different properties such as structure, size, shape and surface and surface charges, behavior, and extent of particle accumulation and dissociation (Ion *et al*., 2010). This technology has proven to be good in managing resources in the agricultural field, food delivery mechanisms in plants, improving soil fertility, recycling agricultural residues, improving the efficiency of microorganisms in decomposing waste and toxic substances, in food processing and packaging, and in assessing risks (Floros *et al*., 2010). It is also used in sensors based on nano-detec-technology such as biosensors, electrochemical and optical heavy metals detection (Dixit *et al.*, 2015 and Ion *et al*., 2010). So that agricultural bioremediation leads to sustainability and restoration of the soil's natural properties (Dixit *et al*., 2015).

Risks regarding the use of nanotechnology

There is a growing interest in nanomaterials technology with their new properties, such as chemical reactivity, bioactivity and bioavailability. Nanotechnology has different applications in the food and agricultural sector, for example: Pesticides, diseases, fertilizers and growth stimulants,
Additives and nutritional supplements, Food packaging, packaging and storage. Manufactured nanomaterials are frequently released into the environment. Some research indicates that nanomaterials manufactured from chemicals can have high toxicity to aquatic life, bacteria, human cells and tissues. Therefore, it is necessary to check its potential toxicity, before it can be used.

Green nanoparticle synthesis

Chemical production of nanoparticles leads to the formation of toxic compounds with harmful effects. While producing them by physical methods is expensive. This led to the development of the production of nanoparticles using green synthesis, which is safe and environmentally friendly. Green synthesis can be done using various types of medicinal and aromatic plants, wild plants and microbial microorganisms including bacteria, fungi, actinomycetes, algae, etc. and spices. This morphology is biologically , sustainable and economically beneficial, unlike the chemical plant and that this synthesis is important as a nano bio-fertilizer; Nano bio-pesticides and diseases and nano biological plant growth stimulators.

Biological nano molecules are also synthesized from proteins, enzymes, sugars and whole cells, which leads to the stability of nanoparticles easily and interaction with other biomolecules, increasing anti-microbial activity (Botes and Cloete, 2010). Some studies showed that the use of bio-silver nanoparticles was more effective as an antibacterial compared to the chemically produced antimicrobial, which was 20 times more active (Sintubin *et al*., 2011). Another study showed that the use of nano algae cells Spirulina platensis led to increased plant growth (Govindaraju *et al.*, 2008).

Applications of green nanotechnology

Composite green nanomaterials play an important role in various fields of technology. The products consisting of this technology can be used to achieve sustainable development. (Tailor *et al*., 2022, Table 1).

Nano fertilizer

In general, fertilizers play a major role in increasing agriculture, as it is important for plant growth, development and production. The emergence of the green revolution and the use of chemical fertilizers to improve soil fertility and increase crop production, caused environmental problems, which led to the creation of alternatives to chemical fertilizers, including the use of biological fertilizers consisting of known microorganisms used in the formation of biofertilizers. The biological manufacture of nanoparticles from microorganisms (Haggag *et al.*, 2018; De FranÃ§a *et al*., 2020) or from different parts of plants (Abbasifar *et al*., 2020) to produce biofertilizer represents a new revolution that has more impact on plant productivity. Nanoparticles are adsorbed into plant cells through aquaporins, ion channels or cytokinesis, and form complexes with transporter membranes through the roots. Nanoparticles can be surrounded by nutrients by encapsulation of polymer nanoparticles, adsorption on nanoparticles, attachment to nanoparticles via bonds, as well as synthesis of nanoparticles composed of the nutrients themselves (Leiderer *et al*., 2022). Nano bio-fertilizers are applied to plants directly in a dry form by spreading or mixing biofertilizer with seeds or liquid, where the seeds or paper-based biofertilizer can be soaked or mixed into the soil, and through hydroponics (Solanki *et al.*, 2015 and Siddiqi and Husen, 2017) (Tailor *et al*., 2022) as seen in Table 1.

Nano pesticides

Many crops are exposed to biological stresses and infected with many diseases from bacterial, fungal, viral, nematode and insect pests.

Nanotechnology also plays a big role in the management of diseases and pests (Haggag *et al.*, 2018 and Farhat *et al*., 2018 and (Song *et al.*, 2022b). The use of green synthesis for nano-pesticides and pathogens showed significant effects, as the same case with pesticides and fungicides (Haggag and Eid, 2022). Composite green nanomaterials play a vital role in their antibacterial action (Acharyulu Naika *et al.* 2015) and for fungi (Sanghi and Verma 2009) and for parasites (Velayutham *et al*., 2012). For example, copper nanoparticles have been biosynthesized by using pomegranate peel extract (Kaur *et al*., 2016). Silver nanoparticles were synthesized using a number of fungi due to their ease of isolation, processing and production of extracellular mass and enzymes, as *Aspergillus terreus* , *Fusarium acuminatum* and *Fusarium pallidoroseum* isolated from infected ginger (Bansal *et al.*, 2017a).

Several studies have shown production of silver nanoparticles from plant leaf extract such as *Azadirachta indica* (Shankar *et al.*, 2004), *phyllanthin* extract (Kasthuri, *et al.*, 2009), Mentha piperita (Parashar *et al.*, 2009). Ocimum sanctum (Mallikarjuna *et al*., 2011), ethanolic extract of marigold flower (Kaur *et al.*, 2011) and kinnow extract (Bansal *et al.*, 2017b). Also, the case of fertilizers, different types of nanomaterials are used, such as; nano biological organisms and plants in the form of polymers, dry and liquid form and capsules. Nano-pesticides are characterized using techniques such as infrared spectroscopy (IR), dynamic light scattering (DLS), and electron microscopy (Tailor *et al.*, 2022) as seen in Table 1.

Nano plant growth stimulators

Sustainable agriculture needs a minimum of agricultural chemicals to batter environmental damage. The use of nanomaterials leads to improve crop productivity and food security, as it improves seed germination, growth, development and adaptation of plants, in addition it has low cost. Some research has shown that nanomaterials can enhance water absorption and stimulate the plant's enzymatic and immune system, thus improving plant growth and development (Song *et al.*, 2022 a, Haggag *et al*., 2018 and Haggag and Eid, 2022). Studies also confirmed that nanomaterials remain in the soil and water during the entire period of cultivation, which encourages germination, growth and production. Nanitinium was synthesized to induce ancient spinach seed germination, plant growth and productivity and prevent environmental pollution (Zheng *et al.*, 2005).

Table 1. Application of nanoparticles in organic farming synthesized through green synthesis (Source: Tailor *et al.*, 2022)

Nano-fertilizers	Size	Source	Effective on
Zn	< 100 nm	Basil Plant extract	Basil Plant
Cu	>100mm	Basil Plant extract	Basil Plant
Fe	1>45-2.20	Zeolite	-
Fe	< 20 nm	Leonardite potassium humate	Soyabean
Fe|Mn	< 25 nm	Bacteria supernatant containing auxin complex (indole-3-acetic, IAA	-
Mn (II/III)	44 nm	Leaf extract of Adalodakam	-
MgO	38 to 57 nm.	Enterobacter sp. RTN2	*Oryza sativa* L.
Cu-Zn|CNFs	34/98 nm	PVA-Starch	Garden soil
Ca-P/Nano-NPK/ Urea-NPK		Biomimicking of bone composition	Wheat
Nano-pesticides			
Ag	< 100 nm	Passiflora foetida	
Ag	70-140 nm	Leaf aqueous extract of Manilkara zapota	*M. domestica*
Ag	-	Peepal tree, Ficus religiosa (FR) and banyan tree, Ficus benghalensis	*Helicoverpa armigera*
Cu	15.67–62.56 nm	Aqueous extract of *Metarhizium robertsii*	*Anopheles stephensi*, *Aedes aegypti*, *Culex quinquefasciatus*, *Tenebrio molitor*
Au	< 100 nm	*Simarouba glauca*	Gram positive and Gram negative bacteria
Zn	76.2 to 183.8 nm	*Aspergillus niger* biomass	*Holotrichia* sp.
Zn	21.3 nm	Pongamia pinnata leaf extract	*Callosobruchus maculatus*
Zn	21-35 nm	Plasma assisted	*B. glumae* and *B. gladioli* (Pathogen of rice plant
Nano-plant growth promoter			
Zn(II) complex	<20nm	*Trichderma longibrachiatum*	Vicia feba
Ag complex	3.63–8.68	Polysaccharides of Chlorella vulgaris	Triticum vulgare and Phaseolus vulgaris
Ag complex	25 to 50 nm	*Bacillus siamensis* strain C1,	Rice seedlings
FeO	20–80 nm	*Cassia occidentalis* L. flower extract	Pusa basmati rice seeds
Nanohydroxyapatite	30±5nm	*Bacillus licheniformis*	Soil application
Nano-TiO2	20-30 nm		*Oryza sativa* L

Future prospective

To overcome the challenges and problems in agriculture, food processing and environmental pollution, it is necessary to turn to modern technology. To take sustainable organic farming as an ecosystem method, containing biodiversity. The use of biological organisms is important to meet the challenges and the food chains and the energy associated with them. The use of new technologies, including the use of biological nanomaterials, leads to maximizing production in agriculture and improving soil and environmental properties. The beneficial nanomaterials can be produced from plant extracts. They are non-toxic and safe and are synthesized via a more stable, stable and effective green route compared to produce by physical and chemical methods. Therefore, the future and modern technology is nano synthesis technology and its use in organic agriculture that helps to provide safe food chains such as using fertilizers, pesticides, nano-diseases, nano-herbicides, growth enhancers and precision farming techniques, smart feeds, improving food quality and biodiversity. It needs more attention in future studies in the field of agricultural nanotechnology or nanomaterials.

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