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REVIEW ARTICLE

Nanotechnology and Its Scope in Sustainable Agriculture: A Review

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ABSTRACT
One of the major goals of the sustainable agriculture is meeting the global food demand with sustainable productions in agriculture. In the field of nanotechnology, an expectation is that the rapid development for an economic driving force to emerge in this agricultural scenario. Recently nanoparticles have been used for developing smart agricultural systems. For instance, Nano-sensors use has been reported for the identification of the health status of plant. Early detection of any health problems before the plants show its symptoms will be much more beneficial to control or increase the resistance towards it can be easily achieved by precise and specific remedy action. The nanotechnology in the field of agriculture has greater emphasize in reducing cost of cultivation, increase the income and also have role sustainable use and conservation of resources to the optimum level of requirements by the plants. This also encourages the researches and farmers to carryout research and farming, respectively, at a large scale. The potentiality of modern tools developed based on the nanotechnology is worth enough to deal with the agricultural problems and to create revolution in the agriculture system. In this review paper, the outstanding contributions of nanotechnology in the agriculture sector through its best potentiality of the nanotechnology-based tools to meet global food requirement through achieving the increased and sustainable production in agriculture sector.
Key words: *Nanotechnology; sustainable agriculture; Global food security; Nanoparticles uses.*

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INTRODUCTION

Sustainability is nothing but a balance between the production i.e., agriculture and food and the natural resources. It is true that all these resources are gifts of nature and we are responsible for its efficient utilization for our survival and also for over next generations. Apart from over exploitation of natural resources, we are contaminating our environment by the excess use of synthetic chemicals. Consistently around 2.5 million tons of pesticides are utilized for yield assurance. It has been assessed that over 90% of the connected plant assurance synthetic substances are being lost to air and water [7]. It is a high time to think about our environment at the same time about the exponential growth of population and its increasing demand [15, 24, 42].

Agriculture always hits primary position among all the sectors since it produces and provides raw materials for food and feed industries. Now a day's agriculture is not just growing crops and getting a bumper yield, above that it is moving through a road which through light on ecosystem balance, environmental sustainability and nutritional security [39]. No doubt that this journey needs new, innovative and worthy technology support. Nanotechnology is one such technique which got acceptance due to its miniature dimension. According to recent research works, nano-technology has the capacity to revolutionize agricultural systems [4, 21, 30].

Nanotechnology helps in sustaining agriculture and environmental by production of pesticides and chemical fertilizers through the utilization of nano particles and nano capsules particles having the ability to control or delayed delivery. They also have the ability to alter the kinetic profiles of drug release,

leading to more sustained release of drugs with a reduced requirement for frequent dosing adding more effective and environmentally friendly alternative[35].

CLASSIFICATION OF NANO-PARTICLES

Feynman's "Plenty of room at the bottom, "simple states the scope of nano technology application for mankind [5]. Nanoparticles are minute particles at nuclear or sub-atomic dimension with measurement somewhere in the range of 1 and 100 nm. The exceptional element of nanoparticles is expected to their physio-chemical properties contrasted with the mass material. Nanoparticles can be produced from an assortment of materials and their activity can be executed relying upon their compound creation, measure as well as shape (Fig.1).

The 'nano' size of the particle is related with its more reactive nature in most sectors including in biological process [26, 27]. This unique property is engraved in the ratio between surface area to the volume of the particles [1, 28, 37]. As like all other sector, agriculture is also in its fast pace and it demands fast, reliable, and low-cost systems for the detection, monitoring, and diagnosis for biological molecules in agricultural sectors [33, 40].

Application of nanotechnology in agriculture

Agriculture is considered as a fundamental operation for survival of mankind but globally its facing so many problems like reduced resource availability, urbanization, overdose and accumulation of fertilizers and pesticides residues, unpredictable rainfall, varying environmental condition and emerging pest and diseases due to effects of climate change. These circumstances are additionally overstated by the developing nourishment request. In this situation it is un- imaginary to think agriculture without chemicals.

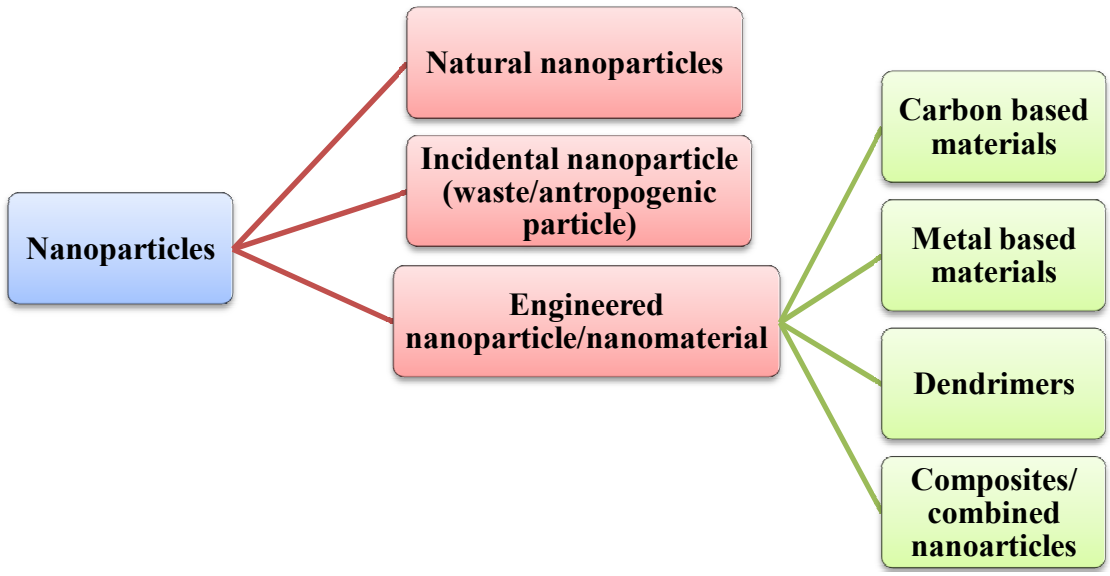

Figure 1: Classification of nanoparticles based on origin

However, every agrochemical has some kind of potential issues such as contamination of water or residues on food products that threat the human being and environmental health. Thus, the precise management and control of inputs could allow reducing these risks to a manageable extent [16]. The development of the high-tech agricultural system with use of engineered smart nano tools will be excellent strategy to make a revolution in agricultural practices, and thus reduce the influence of modern agriculture on the environment as well as to enhance both the quality and quantity of yields [20, 34].Now nano foot is putting its footprints in almost all areas of agriculture from soil treatment to the most recent advancement, the gene transfer.

Nano technology in crop production - Agrochemicals

At present, the smart agriculture is a way to achieve priority of short- and long-term development in the countenance of climate change [11]. This section mainly deals with nano-fertilizers and pesticides including fungicides and insecticides. The nanotechnology can augment the productivity through controlled release of nutrients [10, 24] as well as it can also be utilized for monitoring water quality and pesticides for sustainable development of agriculture [27].

The implication of the nanotechnology research in the agricultural sector is become key factor for the sustainable developments (Fig 2). In the agri-food sector, apposite applications of nanotubes, fullerenes, biosensors, controlled delivery systems, etc. were observed [13,32]. All these are possible by the exploration of two properties of nano-particles; radical changes of the physical–chemical properties of material and huge ratio of surface area to volume. They exhibit very good transduction properties which are being more interesting for analytical purpose of agricultural products [17].

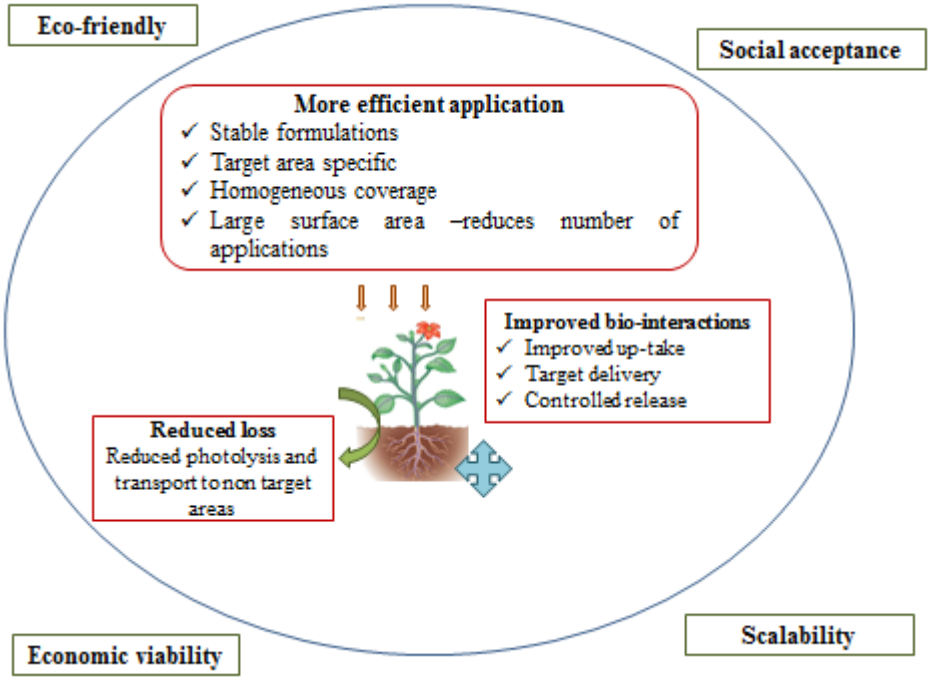

Figure 2: An over view of application of agrochemicals

Soil fortification through nano-fertilizers

High yielding varieties coupled with fertilizer supplement made the dream 'Green revolution', a reality [38]. But due to the over use of agrochemical the health of soil depleted and the excess was washed out by water to nearby water bodies. Balance of nutrients in soil was changed to a wide gap and eutrophication was a visible effect [41]. All these happened not just because of excess use of chemicals but the in ability of small root tips to take up the chemicals.

According to recent studies, nano technology enables the platform for the use of elegant delivery structure for agrochemicals which is safe, target bound and has easy and slow mode of delivery. The surface area to volume ratio offers the platform for sustainable and novel nutrient delivery systems, which will exploit the nano porous surfaces of the plant parts for both soil and foliar application of nutrients. The components of nano fertilizers (Table 1) may include zinc oxide nanoparticles (ZnONPs), silica, iron and titanium dioxide, ZnS/ZnCdSe core–shell quantum dots (QDs), In P/ZnS core–shell QDs, Mn/ZnSe QDs, gold nanorods, $Al2O_3$, TiO_2, CeO_2, and FeO [28,31].

Nanoparticles as a Bio herbicide:

The application of nanotechnology for the management of weeds and other undesirable vegetation is in the juvenile stages of development. Formulation of bioherbicide active ingredient is one of the most critical factors affecting the efficacy in the field [12, 29]. Nanoformulations of bioherbicides have the potential to increase biocontrol efficiency since large surface areas of nanoparticles result in a lower volume of bioherbicide required [22]. The inherent small particle size largely limits the susceptibility of the bioherbicide to environmental conditions. For instants the efficacy of metabolites of the endosymbiotic bacterium Photorhabdusluminescens, which inhabits the entomopathogenic nematode Heterorhabditisindica, a parasite that transmits its toxic metabolites to arthropod pests of agricultural crops [8, 16, 19].

Table1: List of some commercially available nano-fertilizers

Sl. No.	Product	Components	Producer
1	Nano-Gro™	Plant growth regulator and immunity enhancer	Agro Nanotechnology Corp., FL, United States
2	Nano Green	Extracts of corn, grain, soybeans, potatoes, coconut, and palm	Nano Green Sciences, Inc., India
3	Nano-Ag Answer®	Microorganism, sea kelp, and mineral electrolyte	Urth Agriculture, CA, United States
4	BiozarNano-Fertilizer	Combination of organic materials, micronutrients, and macromolecules	Fanavar Nano-PazhooheshMarkazi Company, Iran
5	Nano Max NPK Fertilizer	Multiple organic acids chelated with major nutrients, amino acids, organic carbon, organic micro nutrients/trace elements, vitamins, and probiotic	JU Agri Sciences Pvt. Ltd, Janakpuri, New Delhi, India
6	Master Nano Chitosan Organic Fertilizer	Water soluble liquid chitosan, organic acid and salicylic acids, phenolic compounds	Pannaraj Intertrade, Thailand
7	TAG NANO (NPK, PhoS, Zinc, Cal, etc.) fertilizers	Proteino-lacto-gluconate chelated with micronutrients, vitamins, probiotics, seaweed extracts, humic acid	Tropical Agrosystem India (P) Ltd, India

Plant protection

It has been estimated that pest and pathogens can cause 20 – 40% crop lose [6]. Pesticide application is an age-old practice in agriculture field. Even though it is fast acting easy availability and reliability, more than 90% of these chemicals lost during or after the application [7, 36]. Scientist have developed nanometerials with characteristic features such as shape, pore size and surface properties so that they can then be used as protectants or for precise and targeted delivery via adsorption, encapsulation, and/or conjugation of an active, such as a pesticide [18] (Table 2). In addition to all these, it assures increased efficacy of the activity and stability of the nanopesticides under environmental conditions such as UV and rain [2], significantly reducing the number of applications, thereby decreasing toxicity and reducing their costs [25]. It ensures increase in crop production with least impact on environment [3,8, 16]. Nano-pesticides and herbicides are the most studied area in agriculture after nano-fertilizers. Table 2 explains some of the recent works in this area [9, 14, 19, 22, 23, 37]

Table2: List of some commercially available nano-plant protection

Active Ingredient (AI)	Carrier	Method of action	Formulation
Imazapic and Imazapyr	Chitosan	Cytotoxicity assays	Encapsulation
Piracetam, pentoxifylline, and pyridoxine	Silica	Perfused brain tissue	Suspension
Imidacloprid	Alginate	Cytotoxicity, sucking pest (leafhoppers)	Emulsion
Imidacloprid	Polyacetic acid-polyethylene glycol-polyacetic acid	Decrease the lethal concentration	Encapsulation
Methomyl	Carboxymethyl chitosan	Control release for longer time-period	Encapsulation
Paraquat	Chitosan/tripolyphosphate	Lower cyto- and genotoxicity	Encapsulation

FUTURE PROSPECTS

Progress in agriculture is inseparable for the survival. But it is high time to think in a broad sense which will enable agricultural growth to meet the population demand and also take the sustainability of environment in to consideration. Sustainable agriculture must be taken as an ecosystem method. Scientific approaches and modernization if agriculture should be supported by government policies and with good extension activities so that it should reach the grass root levels. Sometimes it will be only meaning to overcome the hazards side effects caused by unscientific approaches in the food production systems. We should view in advance for long term achievement.

REFERENCES

1. Aziz N., Pandey R., Barman I., Prasad R. (2016). Leveraging the attributes of Mucor hiemalis-derived silver nanoparticles for a synergistic broad-spectrum antimicrobial platform. Front. Microbiol. 7:1984

2. Bhattacharyya A., Duraisamy P., Govindarajan M., Buhroo A. A., Prasad R. (2016). "Nano-biofungicides: emerging trend in insect pest control," in Advances and Applications through Fungal Nanobiotechnology ed. Prasad R., editor. (Cham: Springer International Publishing;) 307–319.
3. de Oliveira J. L., Campos E. V., Bakshi M., Abhilash P. C., Fraceto L. F. (2014). Application of nanotechnology for the encapsulation of botanical insecticides for sustainable agriculture: prospects and promises. Biotechnol. Adv. 32: 1550–1561.
4. Dimkpa C. O. (2014). Can nanotechnology deliver the promised benefits without negatively impacting soil microbial life? J. Basic Microbiol. 54 889–904.
5. Feynman R. P. (1996). No Ordinary Genius: The Illustrated Richard Feynman. New York, NY: W.W. Norton & Company.
6. Flood, J. (2010). The importance of plant health to food security. Food Secur. 2: 215–231
7. Ghormade, V.; Deshpande, M.V.; Paknikar, K.M. 2011. Perspectives for nano-biotechnology enabled protection and nutrition of plants. Biotechnol. Adv. 29: 792–803
8. Grillo R., Abhilash P. C., Fraceto L. F. (2016). Nanotechnology applied to bio-encapsulation of pesticides. J. Nanosci. Nanotechnol. 16: 1231–1234.
9. Grillo R., Pereira A. E., Nishisaka C. S., de Lima R., Oehlke K., Greiner R. (2014). Chitosan/tripolyphosphate nanoparticles loaded with paraquat herbicide: an environmentally safer alternative for weed control. J. Hazard. Mater. 27: 163–171.
10. Gruere G. P. (2012). Implications of nanotechnology growth in food and agriculture in OECD countries. Food Policy 37 191–198.
11. Helar G., Chavan A. (2015). Synthesis, characterization and stability of gold nanoparticles using the fungus Fusarium oxysporum and its impact on seed. Int. J. Recent Sci. Res. 6 3181–3318.
12. Hynes RK, Boyetchko SM .(2006). Research initiatives inthe art and science of biopesticide formulations. Soil Biol Biochem 38:845–849
13. Ion A. C., Ion I., Culetu A. (2010). Carbon-based nanomaterials: Environmental applications. Univ. Politehn. Bucharest 38 129–132.
14. Jampilek J., Zaruba K., Oravec M., Kunes M., Babula P., Ulbrich P. (2015). Preparation of silica nanoparticles loaded with nootropics and their in vivo permeation through blood-brain barrier. BioMed Res. Int. 812673p.
15. Johnston B. F., Mellor J. W. (1961). The role of agriculture in economic development. Am. Econ. Rev. 51 566–593.
16. Kah M., Hofmann T. (2014). Nanopesticides research: current trends and future priorities. Environ. Int. 63: 224–235.
17. Kandasamy S., Prema R. S. (2015). Methods of synthesis of nano particles and its applications. J. Chem. Pharm. Res. 7 278–285.
18. Khandelwal, N.; Barbole, R.S.; Banerjee, S.S.; Chate, G.P.; Biradar, A.V.; Khandare, J.J.; Giri, A.P. 2016. Budding trends in integrated pest management using advanced micro-and nano-materials: Challenges and perspectives. J. Environ. Manag. 184: 157–169
19. Kumar S., Bhanjana G., Sharma A., Sidhu M. C., Dilbaghi N. (2014). Synthesis, characterization and on field evaluation of pesticide loaded sodium alginate nanoparticles. Carbohydr. Polym. 101: 1061–1067.
20. Liu R., Lal R.(2015). Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Sci. Total Environ. 514 131–139.
21. Manjunatha, S.B.; Biradar, D.P.; Aladakatti, Y.R. (2016). Nanotechnology and its applications in agriculture: A review. J. Farm Sci., 29, 1–3.
22. Maruyama C. R., Guilger M., Pascoli M., Bileshy-José N., Abhilash P. C., Fraceto L. F., (2016). Nanoparticles based on chitosan as carriers for the combined herbicides imazapic and imazapyr. Sci. Rep. 6:23854
23. Memarizadeh N., Ghadamyari M., Adeli M., Talebi K. (2014). Preparation, characterization and efficiency of nanoencapsulated imidacloprid under laboratory conditions. Ecotoxicol. Environ. Saf. 107: 77–83.
24. Mukhopadhyay S. S. (2014). Nanotechnology in agriculture: prospects and constraints. Nanotechnol. Sci. Appl. 7 63–71.
25. Nuruzzaman M., Rahman M. M., Liu Y., Naidu R. (2016). Nanoencapsulation, nano-guard for pesticides: a new window for safe application. J. Agric. Food Chem. 64 1447–1483.
26. Pokropivny V., Lohmus R., Hussainova I., Pokropivny A., Vlassov S. (2007). Introduction to Nanomaterials and Nanotechnology. Tartu: University of Tartu; 225.
27. Prasad R. 2014. Synthesis of silver nanoparticles in photosynthetic plants. J. Nanopart.
28. Prasad R., Pandey R., Barman I. (2016). Engineering tailored nanoparticles with microbes: quo vadis. WIREs Nanomed. Nanobiotechnol. 8 316–330.
29. Prasad, R.; Bhattacharyya, A.; Nguyen, Q.D. (2017). Nanotechnology in sustainable agriculture: Recent developments, challenges, and perspectives. Front Microbiol. 8: 1–13
30. Rai V., Acharya S., Dey N. (2012). Implications of nanobiosensors in agriculture. J. Biomater. Nanobiotechnol. 3 315–324.
31. Rameshaiah, G.N., Pallavi, J. and Shabnam, S., (2015). Nano fertilizers and nano sensors–an attempt for developing smart agriculture. Int J Eng Res Gen Sci, 3(1), pp.314-320.
32. Sabir S., Arshad M., Chaudhari S. K. (2014). Zinc oxide nanoparticles for revolutionizing agriculture: synthesis and applications. Sci. World J. 2014:8

33. Sagadevan S., Periasamy M. (2014). Recent trends in nanobiosensors and their applications - a review. Rev. Adv. Mater. Sci. 36 62–69.
34. Sekhon B. S. (2014). Nanotechnology in agri-food production: an overview. Nanotechnol. Sci. Appl. 7 31–53.
35. Sharon, M., Choudhary, A.K. and Kumar, R., (2010). Nanotechnology in agricultural diseases and food safety. *Journal of Phytology*.
36. Stephenson, G.R. 2003. Pesticide Use and World Food Production: Risks and Benefits; ACS Publications: Washington,DC, USA.
37. Sun C., Shu K., Wang W., Ye Z., Liu T., Gao Y. (2014). Encapsulation and controlled release of hydrophilic pesticide in shell cross-linked nanocapsules containing aqueous core. Int. J. Pharm. 463: 108–114.
38. Thakur, S.; Thakur, T.; Kumar, R. (2018). Bio-Nanotechnology and its Role in Agriculture and Food Industry. J. Mol.Genet. Med., 12: 1–5.
39. Thornhill S., Vargyas E., Fitzgerald T., Chisholm N. (2016). Household food security and biofuel feedstock production in rural Mozambique and Tanzania. Food Sec. 8 953–971.
40. Vidotti M., Carvalhal R. F., Mendes R. K., Ferreira D. C. M., Kubota L. T. (2011). Biosensors based on gold nanostructures. J. Braz. Chem. Soc. 22 3–20.
41. Xiong, T.; Dumat, C.; Dappe, V.; Vezin, H.; Schreck, E.; Shahid, M.; Pierart, A..(2017). Copper Oxide Nanoparticle Foliar Uptake, Phytotoxicity, and Consequences for Sustainable Urban Agriculture. Environ. Sci. Technol, 51: 5242–5251
42. Yunlong C., Smit B. (1994). Sustainability in agriculture: a general review. Agric. Ecosyst. Environ. 49 299–307.