Nanotechnology in Agriculture: Opportunities, Potential & Constrains

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INTRODUCTION

Currently, nanotechnology in India has achieved a prime position and attracted tremendous attention. Moreover, the consequences of innovative approaches of nanotechnology are framing infrastructure of 21st century as the 'nano-century'. Therefore, Government of India is also playing fundamental role since 2001 by funding and developing scientific centers dedicated towards nanotechnological researches with aim of exploiting nanotechnology for benefit of mankind. The first step towards achieving the goal was launching of Nanoscience and Technology Initiative (NSTI) in the Tenth Five Year Plan (2002-2007) with budget of roughly 60 million rupees. Further, the Department of Science and Technology (DST) took lead in expanding the descendent of the NSTI by creating nano-mission with budget of 10 billion rupees for five years. Moreover, in the Eleventh Five Year Plan (2007-2012), the DST alone has granted 193 billion rupees. Afterward many other government agencies got involved in funding and initiating nanotechnology R&D that include Department of Biotechnology, Department of Atomic Energy, Council for Scientific and Industrial Research, Indian Council for Medical Research, the Defense Research and Development Organisation etc. Most importantly, in 2004 National Centre for Nanomaterials was also constructed in collaboration with the USA, Russia, Japan, Germany and Ukraine.

Presently, the achievements of nanotechnology based research in India could be estimated by the fact that, India gained global rank 6th in 2009 in terms of publication whereas earlier in 2000 global rank 17th was attained. Various Indian research institutes contributed tremendously in achieving this position at global level and due to this India has been labeled as '(an)emerging nano-power'. However, besides publication, the patenting activity earlier was not up to the mark and was quite low as out of 1,356 patents filed in the IPO, only 46 patents had been granted to Indian institutions till late 2015. It is interesting to note that the major areas for patenting worldwide include pharmaceuticals, electronics and nano-polymers.

Nanotechnology in agriculture

Though, in past decade the concept of nanotechnology in India has gained noteworthy attention due to its multidimensional applications in the field of pharmaceuticals, electronics, cosmetics etc. But, implications of nanotechnology in agricultural field are still mostly unexplored. The planning commission of India has also recommended nanotechnology for enhancing agricultural productivity. Afterwards several states viz. Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka and Tamil Nadu have initiated research programme for linking nanotechnology to agricultural sector. Nowadays, when agricultural sector is getting modernized day by day, the integration of nanotechnology has provided novel and advanced solutions to many challenges coping with agriculture. The major threat to agricultural production is imposed by various

kinds of phytopathogens causing serious diseases leading to huge economic losses. Earlier the idea of green revolution witnessed indiscriminate use of chemical pesticides for plant disease management making the agro-ecosystems unsustainable. Globally, around 2 million metric tons of chemical pesticides are used annually for controlling pathogens and pests with an expected rise to 3.5 million metric tons in next 2 years. Obviously, this application makes successful control over plant diseases but on the other hand it also gave birth to many environmental and health hazards followed by reduced soil fertility, development of pesticide resistant pathogens and high accumulation of pesticide residue in food chains. Subsequently, the more sustainable approach of using biopesticides emerged where agriculturally important microbes are being used as biocontrol agents for plant disease management. But most recently, nanoparticles based strategy is gaining considerable attention, agriculture owing to its unique properties, as compared to biopesticides.

Biopesticides versus Nanoparticles based formulations

In the last few decades, there was upsurge in demand for biopesticides due to rising awareness of the ill effects of chemical pesticides. Biopesticides comprise of beneficial microbes and provide environment friendly means of controlling plant diseases and hence, currently 9.9% of the global market is shared by biopesticides as compared to 1.1% share of chemical pesticides. However, there are some major concerns associated with their usage and to tackle them. Recently innovative approach of harnessing nanotechnology in agriculture is gaining noteworthy consideration. As compared to biopesticides, nanoparticles based formulation carries major advantages in terms of their high on-field stability, high environmental compatibility, high surface area and maximum coverage at very low dose.

Employing nanoparticles based formulation for enhancing agricultural production

Nanoparticles (NPs) generated through nanotechnology in the size range of 100 nm or less, hold promising applications in agriculture due to their exclusive physical, chemical and biological characteristics. These nanoparticles are highly stable with large surface area and provide size dependent qualities. Till now, many physical and chemical methods ate known for synthesis of nanoparticles, for example, high energy ball milling, are-discharge, laser pyrolysis or abalation, electrochemical, chemical vapor deposition, microemulsion sol-gel and reverse precipitation. These methods involve a myriad of inorganic and organic materials and are expensive, unstable and not environment friendly. Therefore, presently biological means of synthesizing nanoparticles using biomolecules of either plant or microbial origin are getting more successful as these biomolecules are of low cost, non toxic and environment friendly.

Moreover, it provides new opportunities to utilize agriculturally important microbes for developing nanoparticles based formulation pointing towards exciting possibilities of nanofarming. Such biofabricated nanoparticles could be of great potential exhibiting excellent antifungal activity against a broad range of phytopathogens. On the other hand, concept of nano-fertilizer has also received tremendous attention for their balanced crop nutrition. The application of innovative technology of nano-fertilizer in agriculture has resulted into significant increase in crop yield.

The beneficial use of nanoparticles for enhancing crop productivity has become the latest topic of research in many developing countries. Most importantly, nanotechnology has opened a new avenue for precision agriculture by serving as operational means of disease control and enhanced crop production.

Table 1. Beneficial role of Nanoformulations over Biopesticides

Parameters	Biopesticides	Nanoparticles based formulations
On-field stability	Low	High
Shelf-life	Major issue & determine efficiency	Not required
Environmental compatibility	Low (efficiency of biopesticide affected due to fluctuating environment	High (unaffected by the external environment)
Size-dependent qualities	No	Yes
Surface area	Low	High
Coverage	Moderate	Maximum
Required dose	High (area dependent dose)	Very low (cover large area at low volume)

The multifarious applications of NPs in agriculture have been documented in Table 2.

Table 2. Various applications of Nanoparticles based formulation in Agriculture.

Nanoparticles	Applications
Nano-encapsulated agrochemicals	Control of phytopathogens
Nano capsulated agrochemicals	Control of parasitic weeds
Silver Nanoparticles (AgNPs)	Control of phytopathogens
Titanium di-oxide (TiO2) NPs	Broad spectrum of antimicrobial activity & can reduce various plant diseases by serving as an antifungal & antibacterial agents
Chitosan polymer NPs	Used for controlled release of NPK
Polymer NPs	Insecticidal activity against adult *Tribolium castaneum*
Silica NPs	Insecticidal activity

Multifarious applications of nanotechnology in agriculture

The multifarious application of nanotechnology as shown in Figure 1 is mentioned below.

i. Use of metal oxide NPs and carbon nanotube for improving seed germination of rainfed crops.

ii. Formulation of nano-fertilizers for enhanced crop productivity.

iii. Development of nanoformulations for plant disease management.

iv. Effective weed control by nano-herbicide.

v. Managing post harvest diseases using nanoparticles base strategy.

vi. Development of nano-sensors and diagnostic devices for monitoring agroecosystem.

vii. Improving soil structure and remediation of toxic metals.

Major constraints associated with nanotechnology usage in agriculture

Besides providing excellent applications

in agriculture there are some biosafety issues which need to be addressed in future research endeavor. Most importantly we cannot ignore the unseen impacts of nanoparticles and hence scientific community should perform detail studies to ensure safety and risks of such nanoformulations. The various associated issues are as follows:

i. Biosafety issues
ii. Impact on environment and soil microbiota
iii. Impact on crops
iv. Interaction of nanoparticles with plant physiology
v. Nanotoxicity towards human, animals.

Futuristic approach

Future studies should deal with biosafety issues related to nanotechnology highlighting their impact on plants, environment and soil. Moreover, various kinds of biotic interactions taking place after application of nanoparticles should not be ignored. What is the fate of applied nanoparticles in environment should be the key point of future research. After dealing with all these issues, nanotechnological applications could be recommended for development of nano-formulations.

Conclusion

Nanotechnology, the rapidly emerging scientific field has achieved a prime position and attracted tremendous attention, nationally and globally. Recognising the lucrative benefits and outcomes, government is supporting and funding research in nanotechnology and developing speciality centres and also framing international collaborations. Though various known risks and hazards are associated with the application of nanotechnology in agriculture and pest control, still, it assures with a new ray of hope for the mankind that, if managed adequately, we may soon have a nano-formulation based healthier, economic and environment friendly- zero chemical pesticide farming across the globe. Thus, a drift in nanotechnology research is the demand of time to address the biosafety issues and curb the risks and hazards associated with nanotechnology products.

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