Nutrient and Pest Management through Nanotechnology

Reeta Joshi[1], Dr. Rohit Bhati[2], Jagdish Kandpal[3]

[1]Reeta Joshi, Assistant Professor, Dept. of Civil Engineering, Quantum University, Roorkee, Uttarakhand, India-247 662
[2]Dr. Rohit Bhati, Assistant Professor, Dept. of Agricultral Studies, Quantum University Roorkee, Uttarakhand, India-247 662
[3]Jagdish Kandpal, Assistant Professor, Dept. of Mechanical Engineering, Roorkee Institute of Technology, Roorkee, Uttarakhand, India-247 662

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Abstract - *Integrated nutrient and pest mgt.(INPM) is the prime mover for the sustainable agriculture. The over dose of fertilizers and unsafe pesticides have led to pollution and serious health issues. Nano science may solve some of the issues by providing nonmaterial of higher performance. An attempt has been made to review the development of Nano fertilizers and Nano pesticides and their influence on crop systems. Nano fertilizers such as N, P, K, Fe, Mn, Zn, Cu, Mo and carbon nanotubes show better release and targeted delivery efficiency. Nano pesticides such as Ag, Cu, SiO_2, ZnO and Nano formulations show better broad-spectrum pest protection efficiency in comparison with conventional pesticides*.

Key Words: **Agriculture, Nanotechnology, Nano fertilizer, Nano pesticide, Pest control**

1. INTRODUCTION

The escalation of the food production for fulfilment of food requirement of increasing population is one of the major challenges in the world. The growth of population is increasing continuously and reached up to 7.37 billion. To overcome this situation, the use of chemical fertilizers and pesticides are being used in farming system from previous five decades. The consumption of total pesticide has increased from 196 to 516 million pounds only in USA.

In reality, the use of chemical fertilizers and pesticide has increased the food production many times but reduced food quality and soil fertility. It has been found that 50 to70% of chemical inputs remains unused by leaching, mineralization and bioconversion. Chemical fertilizers and pesticide residues have affected the human health and also destabilized the sublevels of ecosystem (i.e. soil microbial flora, parasites and marine environment) by runoff and eutrophication (**CHIPPA et al 2016).**

Therefore there is need to improve conventional farming practices into smart practices by the involvement of advanced technologies like nanotechnology for sustainable agriculture. Nanotechnology is the fifth revolutionary technology of the century after biotechnology. It showed wide application spectrum in many disciplines like agriculture, medicine, biology, physics, chemistry, material science, electronics energy and environment. In this technology, we study nano meter (1–100 nm) size materials and theirs. At Nano scale, material has specific physical, optical, mechanical and chemical characteristics in comparison with their bulk form.

Nanotechnology is the emerging technology of this decade and can be a prominent application in agriculture sector (**Chhipa and Joshi 2016**). The Nano tools in the form of Nano fertilizer and Nano pesticide have been modifying conventional farming practices into precision farming. Different types of nanoparticles such as carbon nanotubes, Cu, Ag, Mn, Mo, Zn, Fe, Si, Ti, their oxides, and nano formulations of conventional agricultural inputs like phosphorus, urea, sulphur, validamycin, tebuconazole and azadiractina have been converted into Nano pesticide and Nano fertilizer.

Nano form has shown results within optimum concentration on seed germination, plant growth and production. Similarly, nano pesticides have displayed positive impact on control of plant pest and disease (**Kashyap et al. 2015; Parisi et al. 2014; Delfani et al. 2014**). Nano forms deliver active ingredient to the plant by encapsulation inside nanomaterial or within Nano porous material, Nano coating by polymers and Nano emulsion or nanoparticle form (**DeRosa et al. 2010**).

It is hypothesized that Nano tools performed controlled release capacity of agriculture inputs which could be helpful in maintaining eco balance and provide sustainable solutions to climate change and environmental pollution. The site-specific and controlled release of active ingredients of agricultural inputs reduces the amount and cost of fertilizer and pesticide expense on farmers.

Further, reduction of chemical fertilizers and pesticide lead to improving the soil health and maintain soil geo- biological cycle. This improves the food and nutrition quality of the produced crop. In this paper an attempt has been made to review the use of nanotechnology in advancement of agricultural inputs into nano fertilizer and nano pesticide leading to sustainable agriculture

1.1 Nanotechnology in agriculture

Nanotechnology has potential for sustainable agriculture practice. It is expected that it will lead towards precision farming. Precision farming aims for improved crop yield improvement by monitoring environmental variables and applying controlled target action for a situation (**Chen and Yada 2011**).

The use of Nano formulation, Nano encapsulation and functionalized nanomaterial of next-generation fertilizers and pesticides provides site-specific and controlled delivery of active ingredients (fertilizers and pest protectant) to plants and reduces excess run-off (**Nair et al. 2010; Ghormade et al. 2011; Khot et al. 2012**).

The development of smart delivery system in the form of Nano fertilizer, Nano pesticide, Nano herbicide and Nano sensor has been open up new mode of applications for sustainability of agricultural sector (**Scott and Chen 2013**).

Nano-fertilizer

Nano-fertilizer are Nano-materials, responsible for providing one or more types of nutrients to the growing plants, and support their growth and improve production (**Liu and Lal 2015**). Based on plant nutrient requirement, nano fertilizer is divided into following categories (A) macro- and (B) micro-Nano-fertilizer, (C) Nano particulate fertilizer

1.2 Macro-Nutrient Nano-fertilizerz

Nutrient is required in large amount in traditional farming practices. Nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), sulphur (S) and calcium (Ca) are as macronutrients for plant growth. Increasing food production demand may push up macronutrient fertilizer requirement up to 263 MT by 2050 (**Alexandratos and Bruinsma 2012**).

High-volume-to-surface ratio of nanomaterial reduces the amount and increases the efficiency of macronutrient Nano-fertilizer in comparison with traditional fertilizers. In this regard, many researchers have developed macronutrient Nano-fertilizer and used this at laboratory and field scale. **Liu and Lal (2015**) and **Ditta et al. (2015)** have reviewed the use of Nano-fertilizer in agriculture. Urea-coated zeolite chips and urea-modified hydroxyapatite nanoparticles have been synthesized as a source of N shown their capabilities as slow and controlled release of N for long time period (**Millan et al. 2008; Kottegoda et al. 2011**). Further, **Delfani et al. (2014)** developed Mg NP as alternate of Mg and found 7% increment in Vigna unguiculata seed weight.

2. Micronutrient Nano-fertilizer

Micronutrients are trace element which is required in minute quantity (B100 ppm) but essential for different metabolic processes in plants. Nano form of micronutrients improves their bioavailability to the plants and shows a significant improvement in plant growth and nutrition quality.

In this regard, **Delfani et al. (2014)** used Fe NP on blacked eyed pea and measured 10% increment in chlorophyll content in leaves. Similarly, in G. max chlorophyll content was increased by Fe NP at 30–60 ppm concentration (**Ghafariyan et al. 2013**). Spray of Mn NP on Vigna radiate increased 52% root length, 38% shoot length 71% rootlet and 38% biomass at 0.05 ppm concentration in comparison with bulk $MnSO_4$. Zinc is the essential micronutrient and regulates the different enzymatic activities in plants. ZnO NP showed a significant improvement in biomass, shoot length, root, chlorophyll and protein content, and phosphate enzyme activity in Vigna radiate, Cicer ariatium, Cucumis sativas,

Raphanus sativus, Brassica napus and Cluster bean (**Zhao et al. 2013; Raliya and Tarafdar 2013**). In the case of copper, Cu NP improved photosynthesis in Elodea desaplanch by 35% at low concentration (**Nekrasova et al. 2011**) and seeding growth up to 40% in lettuce (**Shah and Belozerova 2009**). Molybdenum nanoparticle also showed improved microbial activity and seed growth in chickpea after combined treatment with nitrogen fixation bacteria (**Taran et al. 2014**).

Nano-particulate fertilizer

Other nanoparticles such as TiO_2, SiO_2 and carbon nanotubes (CNTs) also showed plant growth promoter activity. TiO_2 and SiO_2 mixture increased nitrogen fixation in G. max and improved seed germination and growth (**Lu et al. 2002**), while TiO2 alone increased total nitrogen, protein and chlorophyll content in Spinacia oleracea (**Gao et al. 2006**).

CNT was also used as fertilizer in vegetables (tomato, cabbage, carrot, rape, onion and cucumber) and crop (soybean, rye grass and corn) and increased plant growth and yield (**Khodakovskaya et al. 2012**). Carbon nanotubes promote water uptake capacity and plant growth by entering into germinating seeds (**Srinivasan and Saraswathi 2010**).

Nano-pesticide

Nano-formulation of traditional pesticide with polymers or metal nanoparticles is in demand. Nano encapsulation of pesticide is advantageous in controlled and slow release of active ingredient by manipulation in outer shell of Nano-capsule, which releases low dose over a prolong time period and reduces excess run-off of unwanted pesticide (**Agrawal and Rathor 2014**).

Site-targeted delivery and stability of active ingredient is another advantage of Nano carriers in plant protection (**Nair et al. 2010**). Similarly, Nano emulsion with water or oil improves the solubility and efficiency of pesticide against different pests (Wang et al. 2007; Liu et al. 2006). Silver nanoparticle (Ag) is broad-spectrum active agent against phytopathogen as Biploaris sorokinniana, Botrytis cinerea, Colletotrichum gloeosporioides, Fusarium culmorum, Phythium ultimum, Phoma, Megnaporthe grisea, Trichoderma sp. Scalerotinia sclerotiorum Sphaerotheca pannasa and Rhizoctonia solani **(Kumar et al. 2010; Gopal et al. 2011)**.

Further, silica nanoparticle with Ag (Si–Ag NP) has been reported 100% active against powdery mildew disease in cucurbits (**Park et al. 2006**). Porous silica nanomaterial is also reported as carrier of validamycin and showed controlled delivery of pesticide (**Liu et al. 2006**). Zn NP has been reported as Nano-fertilizer but showed antifungal activity against Penicillium expansum, B. cinerea, Aspergillus flavus and A. niger (**He et al. 2011; Jayaseelan et al. 2012**). ZnO NP is less toxic to plant in comparison with Ag NP and could be prominent alternative of pesticide.

Similarly, Nano- sulphur and Nano- formulation of hexa conazole are highly effective against plant pathogenic fungi R. solani, Erysiphe cichoracearum and red spider mite Tetranychus utricle. Impact of these Nano-materials on environment and compliances with toxic substance control act should be examined before their commercialization. To prevent their hazardous impact on environment, Nano-pesticide Act should be regulated by federal agencies.

Nanotechnology and traditional practices-a comparision

Currently, Nano-agriculture is focusing on target farming that applies Nano-sized particles with unique properties to boost crop production (**Batsmanova et al. 2013; Scott and Chen 2013**). In the traditional practices, seed germination, plant growth promotion and crop improvement are now being reported successfully replaced by the application of carbon nanotubes as regulators of seed germination and plant growth (**Khodakovskaya et al. 2013**; **Zheng et al. 2005**). The use of Nano-sized bacteriophages has also shown promising biological alternatives to conventional Cu bactericides. Small in size and high-surface-to-volume ratio character of nanoparticles make them more efficient in comparison with their bulk components. Engineered nanoparticles enter into intercellular space through Apo plastic pathway.

Further, through Apo plastic (through cell wall), particles may enter into epidermal and cortical cell to reach endodermis and accumulate uniformly or as aggregate form (**Zhao et al. 2013b**). In contrast **Rico et al. (2011)** hypothesized that simplistic (through cytoplasm) route is a more organized and regulated pathway for movement of engineered nanoparticles into plants. They proposed that binding of nanoparticle with carrier protein is helpful in cell internalization and easy to move through ion channels, aquaporin's and endocytosis.

3. CONCLUSION

Nanotechnology has opened an new domain in agricultural practices that can provide sustainable tools to conventional farming practice in the form of Nano-fertilizer and Nano-pesticide. Nano form of conventional agriculture -inputs provides the site-specific and controlled release of active ingredient that can reduce the excess run-off and prevent eutrophication and residual contamination. The use of encapsulated and metal Nano-fertilizer and Nano-pesticide has been evidenced their promising approach in agriculture. Ca and P hydroxyapatite, Fe, ZnO, TiO_2, Ag nanoparticles and CNT can be used as an alternate of conventional agriculture-input. Further, more research is required in environment impact assessment of Nano-tools before commercialization.

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