Potential use of Nanotechnology in agriculture

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***Abstract*- Nanotechnology has the great potential to make ensure the valuable impact on several agricultural sector like (agronomy, soil science, entomology plant pathology etc), forestry, and environmental challenges, such as urbanization in cities, energy problems in society, and sustainable use of natural resources. However, new environmental, agricultural and human health hazards may be emerged from nanotechnology applications in these areas. The main target of this review is for discussing the promising solutions that nanotechnology may give in agricultural activities, with a specific focus on crucial aspects, challenging issues in different sector, and research needs for occupational risk assessment, environment impact analysis and management in these emerging areas. Nano-fertilizers, (nano-sized macro and micro nutrients, nano-coated fertilizers, or engineered metal-oxide or carbon-based nano materials), and nano-pesticides, nano herbicides (nano-formulations of traditional active ingredients or inorganic nano materials), may provide a controlled release of several agrochemicals, aimed to obtain their fullest biological efficiency without over dosage. Nano-sensors and nano-remediation methods may detect and remove environmental pollutants. Nevertheless, limited knowledge concerning nonmaterial bio safety, adverse effects, harmful effect on environment, fate, and acquired biological reactivity once dispersed into the environment, requires further scientific and technical efforts to assess possible nano-agricultural risks. In this point of view, toxicological research should be aimed to define nano material hazards and levels of exposure along the life-cycle of nano-enabled products, and to evaluate those physic-chemical features affecting nano material toxicity, possible interactions with agro-system co-formulates, and stressors. Overall, this chapter highlights the importance of nanotechnology in agriculture as well as different areas of other disciplines like environment and food technology.**

Keyword: environment impact analysis, nanotechnology, Nano-sensors, environmental pollutants.

I. INTRODUCTION

Nanotechnology is rising out as the greatest tools in current agriculture and expected to become a driving economic force in the near future. Nanotechnology employs different type of chemical agents to implement crop productivity and potentials to reducing the use of huge quantity of agrochemicals. It may afford keener solutions for the current problems in the field of agriculture. Agriculture is considering the backbone of most developing countries like India, Nepal Brazil, with more than 60% of the population dependent on it for their livelihood. At the same times there are so many challenges facing agricultural sector, like climate change, non-reasonable use of resources and usage too much chemical fertilizer, unskilled labour, poor yielding verities **(Raliya *et al*. 2017)**.

Direct applications of nanotechnology in agriculture sector consist of delivery of agrochemicals and herbicide, nutrients, pesticides, smart packing, nanosensors, veterinary care, fisheries and aquaculture, detection of nutrient deficiencies. Nowadays Nano-fertilizers are being used as alternates to huge quantity fertilizers and reduction of soil and water pollution different agrochemicals. Nano-fertilizers help the slow and stable release of micro and macro nutrients and thereby reducing the loss of nutrients and increase the nutrient use efficiency. Nanotechnologies also improve the nutrient use efficiency and minimize the costs of environmental protection, slow-release fertilizers are the excellent replacement of soluble fertilizers. This effort focused on the applications of nanotechnology in agriculture sector improvement, especially in the area of plant nutrient management and plant protection. "Nanotechnology is the art and science of manipulating matter at the nanoscale" the design, characterization, production, and application of structure, device, and system by controlling shape and size at nanoscale **(British standard institution, 2005)**.

It is considered as an emerging field of science widely subjugated in many scientific fields and supposed playing the main role in the field of agriculture and food science in next era, but at present there is lack in scientific studies about its application in agriculture in the worldwide **(Mousavi and Rezaei 2011)**.Plant nutrition is critical for agriculture production and crop quality, and about 40% to 60% of the total world food production depends on the application of fertilizers **(Roberts 2009).**Nanotechnology is working with the least possible particles which raise hopes for increasing agricultural production during encountering problems unsolved traditionally. Nanotechnology applications have huge potential to modify agricultural production by allowing best management and resource conservation inputs of plant and animal production. Nanotechnology provide a great possibility of novel applications in the plant nutrition fields to achieve the future request of the growing population because nanoparticles have exclusive physicochemical characters i.e. high surface area, high reactivity, and tunable pore size.

The purpose of nanoparticle in agriculture sector is to reduce the amount of spread chemicals, minimize nutrient losses in fertilization and increased yield through pest and nutrient management. The significant interests of using nanotechnology in agriculture includes specific applications like nanofertilizers, nanoherbicides and nanopesticides to trail products and nutrients levels to increase the productivity without decontamination of soil, water and protection against various biotic and abiotic stresses. Nanotechnology may act as sensors for monitoring soil physical condition of agricultural field and thus it maintain the health of crops **(Prasad et al., 2017).** For increasing the nutrient use efficiency of applied nutrients with the help of nano clays and zeolites and restoration of soil fertility by releasing fixed nutrients.Nano herbicides are being developed to address the problems in perennial weed management and exhausting seed bank of weed. Levels of environment pollution can be evaluated quickly and effectively by gas sensors and nano smart dust **(Shaimaa and Mustafa, 2015)**. Nanoparticles, whether of natural or manufactured origin, have in the range of 1−100 nm in at least one dimension. Generally, nano meter is about one billionth of a meter *e.g.* Nano emulsion, carbon nanotubes, quantum dots, nanorods, micro and nano-encapsulation etc. Morphology-aspect ratio or size, hydrophobicity, solubility-release of toxic species, surface area or roughness, surface species contaminations or adsorption, during synthesis or history, reactive oxygen species (ROS) O2 / H2O, capacity to producing ROS, structure, composition, competitive binding sites with receptor and dispersion and aggregation are the important characteristics of nanoparticles **(Somasundaran et al., 2010)**.

II. POTENTIAL APPLICATION OF NANOTECHNOLOGY IN AGRICULTURE

Use of nano-fertilizers in agriculture for improving efficiency of slow release of nutrients and also improve efficiency *viz.* Nano-5, Nano-Gro as plant growth regulators; nanopesticides, nanoherbicide encapsulated in nanoparticles for controlled release, nano emulsions for great control of pests e.g. Allosperse delivery system, Nano revolution-2,surfactant and adjuvant; will increase agricultural input use efficiency. Nano sensor in precision farming and nano material for site specific soil and water conservation e.g. Geohumus and Nano Clay helps in efficient utilization of natural resources. Production of nano materials helps in recycling the agricultural waste material ex. Central research institute of cotton, India has developed technology for production of nano cellulose from agricultural residues through this residues can be managed efficiently.

III. APPLICATION OF NANOTECHNOLOGY IN AGRICULTURE AND ALLIED SCIENCES

Nanotechnology have its potential in several fields of science out of them few are in agriculture and allied are food technology, crop improvement (genetic modified crops), seed technology, precision farming (site specific nutriment management), nano-fertilizer for balance nutrient management, plant disease assessment , weed management options through herbicide, biosensors and insect pest management. Controlled Environment Agriculture (CEA) technology, as it exists today, facilitates an excellent platform for the introduction and utilization of nano material in agriculture for improving efficiency. With many of the monitoring and control systems already in place, nano technological devices for CEA that provide “scouting” capabilities improve the grower’s ability to determine the best time of sowing, nutrient management and harvest for the crop, the vitality of the crop and food security issues, such as microbial or chemical deterioration **(Allah, 2012)**.

IV. APPLICATION OF NANOTECHNOLOGY IN PRECISION FARMING

Precision farming has been estimated that to applying input as per demand of the crop that maximize output (i.e. crop production) while minimizing input (i.e. fertilizers, pesticides, herbicides, labour requirement etc.). Precision farming is making use of computers, geological information systems (GIS), global satellite positioning systems (GPS) and remote sensing devices to measure highly localized environmental conditions thus determining whether crops are growing at maximum precisely identifying the nature and location of problems of crops varieties. Precision farming can also help to recycle agricultural waste material and thus keep environmental pollution at minimum extent. One of the major roles for nanotechnology-enabled devices will be increased use of autonomous sensors linked into a global positioning system (GPS) for real-time analysis. These nano sensors could be distributed throughout the field where they can monitor soil conditions and crop growth. The combination of these two technologies in sensors will create equipment of increased sensitivity, allowing an earlier response to environmental changes, For example: (a) Nano sensors utilizing carbon nano tubes or nano-cantilevers has capability to trap and measure small molecules. (b) Nano particles or nano surfaces can be engineered to trigger an chemical signal in the presence of a contaminant such as bacteria and other pests or pathogens. (c) Other nano sensors perform by triggering an enzymatic reaction or by using nano engineered branching molecules called dendrites as probes to bind to target chemical sand proteins **(Tiju and Morrison, 2006)**.

Nano Sensors: Nanotechnology is also being developed to increase soil productivity and crop production. Nano sensors may also monitor crop health and magnetic nanoparticles could facilitate removal of soil contaminants

(Hg, Pb and Zn). "Lab on a chip" technology also could have significant impacts on developing countries.

Nano fertilizers: In the current years nanofertilizers are available in the market in wide range, but mainly the agricultural fertilizers are still not shaped by the major chemical companies in India. Nanofertilizers may contain nano zinc, nikil, silica, iron and titanium dioxide, different core shell gold nanorods, QDs etc. as well as should endorse control release and improve its quality. Studies of the uptake, biological fate and toxicity of several metal oxide NPs, *viz*. AlO, TiO, FeO and ZnO nanoparticles were carried out intensively in the present decade for agricultural production **(Zhang *et al*., 2016)**.So, quantification of nanoparticles is necessary to reduce the toxicological effect of it.

Nanoherbicides: Many weed species approach with single herbicide or repeated use of herbicide with same mode of action in the cropped environment resulting in bad control and herbicide resistance. Developing a target specific herbicide molecule encapsulated along nanoparticles is expected at specific receptor in the roots of target weed species, which enter into roots system and translocated to parts that inhibit glycolysis. This will make the specific weed plant to starve for food and gets killed **(Chinnamuthu and Kokiladevi, 2007)**. In rain fed and irrigated areas, application of herbicides with insufficient soil moisture may lead to less loss as photodecomposition. The controlled action of encapsulated herbicides is expected to take care of the competing weeds with crops. Herbicide with adjuvant application is also available that including nanoparticle that increase the efficiency of herbicide action.

Nanopesticides: The utilization of nanoparticle in plant protection principles and production of food is under-explored area in the future planning. It is recognized that insect are the major ones in the agricultural fields and also in its products of nanoparticles may play a key role in the control of insect pests and host pathogens **(Khota *et al*., 2012)**.The current development of a nano encapsulated pesticide formulation has slow releasing action with improved solubility, specificity, permeability and stability **(Bhattacharyya *et al*., 2016)**. Formulation of nano encapsulated pesticides led to minimize the dosage of pesticides, improve pesticide efficiency and human beings experience to them which is eco-friendly for crop protection **(Nuruzzaman *et al*., 2016)**. So development of non-toxic and promising pesticide delivery systems for increasing crop productivity per unit time basis while reducing the negative environmental impacts to ecosystem **(Grillo *et al*., 2016)**. Recently, few chemical companies openly promote nanoscale pesticides for sale as "microencapsulated pesticides." **(Gouin, 2004)**.Despite they are known as micro emulsions. However, they are really nanoscale emulsions and this technique is commonly used for formulations of organic nanoparticles containing active agrochemicals or substances. A range of formulation types have been suggested including emulsions (e.g., nanoemulsions), nanocapsules (e.g., with polymers) and nanoclays. These products can be used to enhance the use efficacy of existing pesticide active ingredients or to improve sustainability. **(Kookana *et al*., 2014)**.

V. NANOTECHNOLOGY IN AGRONOMY

Nano sensors can be used to determine every small part of a farm how much needs to inputs. As a result, economic efficiency of such inputs (fertilizers, herbicide, seeds and pesticide) is increased and timely needs of crops fulfilled. Nano sensors and nano-based smart delivery systems can help in the efficient utilization of agricultural resources like water, nutrients, light and chemicals through precision farming and site specific nutrient management etc. Through the use of nano materials and global positioning system (GPS) and remote sensing farm managers could detect crop pests or evidence of stress such as drought and nutrient deficiency on the basis of spectral images. Nano fertilizers can be absorbed by plants completely due to more surface area and more supply at action site that save fertilizer utilization and to minimize environmental pollution. Slow-release nitrogen fertilizers are terrific alternatives to soluble fertilizers. Nutrients are released at a slower rate throughout the crop growth as per need of crop biotype without any kind of losses such as leaching, evaporation, surface runoff, adsorption absorption and decomposition. Slow release of different nutrients in the environments could be provided by using zeolites that are a group of naturally occurring minerals that have a honeycomb-like layered crystal structure. This type of interconnection, tunnels and cages can be loaded with nitrogen, phosphorous, calcium, zinc, potassiun and potassium, and a complete suite of minor and trace nutrients. Coating and cementing of nano and subnano-composites have capability to adaptable the release of nutrients from the fertilizer capsule **(Liu *et al.*, 2006)**. A patented nano-composite consists of N, P, K,Ca,Mg,S, micronutrients and amino acids that boost the uptake and utilization of nutrients by grain crops has been reported **(Jinghua, 2004)**.

Seeds of different crop can also be imbibed with nano-encapsulations with specific bacterial strain (*Pseudomonas* spp.) termed as Smart Seed. It will thus reduce seed rate, ensure right field stand, crop quality and improved crop yield. A smart seed can be planned to germinate when adequate water is available that can be dispersed larger than a mountain range for reforestation **(Natarajan and Sivasubramaniam, 2007)**. Coating seeds with nano membrane, which can senses the availability of water and allow seeds to imbibe only at correct time of germination, broadcasting of seeds embed with magnetic particle, detecting the water content during storage to take appropriate measure to diminish the spoilage and use of bio analytical nano sensors to determine ageing of seeds are some possible thrust areas of investigation.

VI. APPLICATIONS OF NANOTECHNOLOGY IN PESTS AND PLANT DISEASES MANAGEMENT

At present days use of synthetic chemicals such as acricide pesticides, fungicides and herbicides is the best and cheapest way to control weed, mites, pests and diseases. Indiscriminate use of these chemicals is causing many problems such as: hazardous effects on human health and on pollinating insects and domestic animals, and entering this material directly or indirectly in ecosystems that affect the ecological foodprint. Appropriate use of these chemicals on the nano scale can be an appropriate solution for this problem. These materials are used as carriers in nano scale has self-regulation, this means that the medication on the necessary amount only be delivered into plant tissue. Nanoparticles for discharge of active ingredients or drug molecules will be at its helm in near future for therapy of all pathological sufferings of crop plants. There are myriad of nano materials including polymeric nanoparticles, iron oxide nanoparticles and gold nanoparticles which can be simply synthesized and exploited as herbicide, pesticide, fertilizer or drug delivery piggybacks **(Sharon *et al.*, 2010)**.

VII. NANOTECHNOLOGY IN FOOD INDUSTRY

Oxygen is a problematic factor in food packaging, as it can be caused food spoilage and discoloration. Nanoparticles have been developed a plastic that preventing the penetration of oxygen as a barrier. Polymer-silicate nano composites have also been revealed to have improved gas barrier properties, mechanical strength, and thermal stability. In recent times, nano-coatings are created for fruit that covering the fruits completely and also prevent of fruit weight loss and shrinkage **(Predicala, 2009)**. Development of smart packaging to optimize product shelf-life has been the target of many companies. Such packaging systems will be able to repair small holes/tears, respond to environmental conditions (e.g. light, temperature and moisture changes), and alert the customer if the food is infected. Nanotechnology can also provide solutions for these, for example modify the permeation behavior of foils, increasing barrier properties (mechanical, thermal, chemical, and microbial), for improving mechanical and heat-resistance properties, developing active antimicrobial and antifungal surfaces, and sensing as well as signaling microbiological and biochemical changes **(Moraru *et al.*, 2003)**.

VIII. CONCLUSION

Among the latest technological advancements, nanotechnology occupies an essential position. It has so many uses in all stages of production, processing, storing, packaging and transport of agricultural food products. For reducing the use of herbicides, pesticides and fertilizers with increased efficiency, controlled release and targeted delivery will lead to precision farming. Modern agriculture is need of hour because traditional agricultural will not be able to feed an ever rising population with changing climate, depleting resources and decrease landscape so use of nanotechnology in agricultural sector is most important for increasing the efficiency and efficacy of fertilizer, herbicide, pesticide and growth hormone.

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