Use of Nanotechnology in Agriculture: A Review

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Abstract **- As climate is changing, agricultural system at global level is facing extraordinary and numerous challenges. To meet the demands of food, of increasing population, use of modern technologies viz., bio and nano technologies is necessary. Nanotechnology is defined as materials, processes and systems which operate at a scale of less than or equal to 100 nano meters (nm). Nano technology has occupied a remarkable place in agriculture and related industries. Nano technology has its applications in different stages of production of agriculture products such as processing, storing packing, transport etc. Using nano technology in sectors like agriculture is economically beneficial. Nano materials are being developed which ensure administration of herbicides, pesticides, fertilizers safely, by controlling the exact time and location of dispersal. To identify the plant pathogens new tools have been introduced into cellular and molecular biology by using Nanotechnology. Nanotechnology has provided solutions to the problems in the food and Agriculture sector by increasing the quality of produce. With the help of nanotechnology increase in the crop production achieved.**

Index Terms **- Nanotechnology, Agriculture, Nano materials, Crop production, Bio technology.**

INTRODUCTION

The importance of agriculture to humans is increasing everyday with the increasing world population. The first important need of any human is food; agriculture is either proportionally or inversely associated with the food production to humans. Uplifting the agriculture the sector is the important aim for developing countries. The agriculture products are not able to satisfy the demands of the increasing world population; therefore there is a need of implementing new technologies in agriculture sector to increase the agriculture production. Modern technologies have been developed to enhance the quality and quantity of the agriculture products such as Bio technology and Nano technology. In order to full fill the food demands of day by day increasing population we have to raise the agricultural productivity by considering plant mineral nutrition as an important factor. This can be done by replacing traditional bulk fertilizers with nanoparticles which provide greater solutions. It has worthier properties that can overcome the challenges like bioavailability, uptake of minerals, enhancing the yield of crop with less wastage of fertilizer with eco-friendly properties. Several studies shown that plant growth, physiology and its development affected by nanoparticles of necessary and unnecessary elements, and use of nanoparticles depends on size of particle, composition, concentration in their mode of application. There is both positive as well as negative effects of Nano fertilizers, this Nano fertilizers can be applied to directly to roots or via foliar spray which show effects on plant and associated microorganism, and it also controls the pest as per according to current studies and analyses. Since the work of research, of nanotechnology in agriculture is, at nascent stage and there is a lack of information on the nanomaterials application in crops. With this review we are enlisting the innovative use and application of nanoparticles in agriculture to reach the rising demands of food and also make the environment feasible. Nano technology has its applications in different stages of production of agriculture products such as processing, storing packing, transport etc. Nano materials are being developed which ensure administration of herbicides, pesticides, fertilizers safely by controlling the exact time and location of dispersal. To identify the plant pathogens new tools have been introduced into cellular and molecular biology by using Nanotechnology. Nanotechnology has provided solutions to the problems in the field of food and agriculture sector by increasing the quality of produce. With the help of

nanotechnology increase in the crop production achieved.

NANOTECHNOLOGY

The word Latin word NANO gives the meaning of "Dwarf ". The name Nanotechnology itself indicated conversion of larger molecules into particles of Nanometre size, during this process of conversion the base material undergoes physical and chemical changes. Nanotechnology is an interdisciplinary field added into various applied sciences such as engineers, chemists, physicists, medical doctors and biologists. The development and targeted research, for analysing, to create changes and to measure materials with super molecular, molecular and atomic dimensions is called as Nanotechnology. Nanotechnology at present is defined as science relating to systems, materials and processes operating at a range of less than or = 100 nanometres (nm). 1 nanometres = billionth part of a meter. The Nano ranges between 1 nanometres (nm) and 100 (nm). Nanomaterials are made of components of very small size; these components have the effects on the properties of materials at macrolevel. Nanotechnology aims in release of herbicides, chemicals or genes in target sites of plants. Nano capsules are effective in penetration of the active substance at the tissue and cuticular lever at a slow and constant rate. The application of this technology with biology using nano particles is called as nanobiotechnology. Nano shells and Nano polymers are most vital nano compounds which have numerous applications in various fields. Nano shells are nano particles with dielectric core which are made up of very thin gold coating. Nano polymers are 3 dimensional structures which are obtained by nano synthesis. Nanomaterials are of several kinds it could be particle, tube, gel, sheet or suspension.

Nanomaterials in agriculture

Essentially when we talk about agriculture multiple areas of agriculture are involved i.e. 1. Crops: grains, legumes, vegetables, fruits, fodder, spices, cash crops, sugar crops, etc. 2. Animal production; poultry, fishery, dairy, etc. 3. Post harvesting technologies: grain preservation, food preservation, storage and transportation. Almost all nanomaterials can be used in agriculture either they can be directly introduced into the soil, they can be incorporated into the plants at different stages of plant growth, nanomaterials to the plants can be applied to the root for root treatment, can be applied to the shoot for shoot treatment, by foliar spray, floral spray and seed treatment. Water can be purified by using nanotechnology.

Nanomaterials are used in increasing animal productivity, in this case nanomaterials are given in the form of feed, injecting, and by skin patches. Increase in milk productivity and increase in meat productivity can be gained by feed additive. Immunity in animals can be increased by injecting. Skin patches are used for slow release. Nanomaterials are used Post harvesting technologies for food preservation, grain processing, storage and transportation of food.

Nanomaterials for seed treatment:

Success of any crop depends on the germination percentage of the seeds therefore Farmers treat the seeds before sowing. The treatment of seeds is done in different ways i.e. by coating of seeds with fungicides, germinating agents to promote faster growth. Seeds are water treated, as we know seed coat is hard and impermeable to water therefore over night soaking of seeds in water allows the motion of water molecules slowly into the seed and activates the metabolic processes and in the next day the germination vigor of the seed increases. These practices are age old practices and have been using by the farmers since ages.

Seed pre treatment with nano materials is done in two ways: 1. by dry coating of nano materials. 2. By aqueous treatment i.e. Nano materials + water. Metal Sulfide nanomaterial is the first nanomaterial based seed treatment that has brought a very positive impact in ten to twelve crops by increasing productivity and competed with the fertilizer application. The metal used is Fe (Iron), the combination of iron and sulfide gives Fes2 (also called as pyrite).

Classification of nanomaterials:

Nanomaterials are classified into two categories i.e. based on shape and geometry and based on chemical structure.

1.Based on shape and geometry:

Based on shape and geometry nanomaterials are divided into following types: nano cages (interior is hollow and porous wall containing metallic nanoparticles, their size ranges from 10 to 150 nm.).Nano crystals (size range is app. 100nm). Nano

belts (these are ribbon like structure, they are thin and sheet like structures, their size range from 30 to 300nm).Nano fibers (these are mesh like structures having a diameter of 100 nm). Nano particles (their size ranges up to 1 nm) nano tubes (they are cylindrical in structures and are hollow).Nano wire (this is a one dimensional nano structural material) Quantum dots (it is a nanocrystal).Nano composites (these are multiphase materials where atleast one of the consecutive phase has one dimension less than 100nm) and many more. And these structures of nanomaterials are exceptionally helpful in developing next generation of biosensors for agricultural applications. In precision farming, where we are talking about pest on the soil assay, how precisely a fertilizer should be applied in order to ensure a sustainable growth of the ecosystem. Then we need to test, we need to have small sensors or micro sensors which would be used or utilised to detect the different contaminants in the soil. So, one of the areas where tremendous amount of a stress has been put in precision farming is developing nano based sensors for agricultural applications

2.Based on chemical nature:

They are organic, inorganic and carbon based. And in the organic we talked about dendrimers, micelles, liposomes, ferritin and most of them are biodegradable and non-toxic and most of them have hollow force and they could be used as nano capsules to delivery any kind of active ingredient or any kind of agrochemicals at a specific site, not only that much of these organic nano capsules could be remain to open up or close according to the electromagnetic radiation or any other form of radiation like heat or some other source of energy.

Inorganic materials which are mostly the aluminium, cadmium, cobalt, copper, silver, gold, iron, zinc, lead. Most of these metal-based are also used to deliver different forms of pesticides or they could even at times could replace the pesticides in order to reduce the requirements of pesticides. There are different forms of inorganic forms. There are metal sulphide, rare earth and metal oxide based once and then we will talk regarding the Carbon based on where in highlighted about fullerenes, grapheme, carbon nanotubes, carbon nano fibres, carbon dots activated carbon, nano diamonds and all these kinds of other structures. So today what you will do will pick up this part where we talk about broadly about the synthesis of Nanomaterials.

Application of different nanoparticles in agriculture:

Zn has been used for seed priming, this increased the seed weight. Ceo2 has been tried on spinach and radish for germination but there are negative results, reduction in germination can be utilized for storage of seeds. Carbon nanotubes are used in tomatoes to enhance seed germination. Water soluble carbon molecules are used in chickpea to increase growth. Silver is used on fenugreek seedlings, this resulted increase in root length, shoot length and leaf length. Molybdenum is used on chickpea seedlings to increase the no of roots and nodule number. Manganese is used on moong bean seedlings to increase the length of shoot and root, dry weight, chlorophyll content, carotenoid content and photosynthetic rate. Citric acid coated cesium oxides are used on radish seedlings, this reduced the seed germination but changes in the seed performance were identified. Calcium carbonates are used on peanut seedlings to improve the seedling growth. Magnesium is used on black eyed pea seedlings to increase the seed weight. Iron is used on black eyed pea seedlings in hydroponics as foliar and seedling to increase the chlorophyll content and weight. Zinc oxides were tried on moong bean and chickpea seedlings it increases root length, shoot length and biomass. Carbon mono-oxides were tried on onion seedlings it increases the root growth. Zinc oxides were tried on cucumber, they were applied into the soil mixture and as well as on the seedlings also it increases the root dry mass and food starch. Copper oxides were applied on water weed seedlings it increases the percentage rate of Cu2O. Fe2O3 were applied on spinach in hydroponics, this increases the plant biomass, root and shoot length. Zinc oxides were applied on chickpea through foliar spray on seedlings, it increases the biomass. Iron is tried on wheat as foliar spray for synthesis of chlorophyll and biomass. As we look into this we observed that various nanomaterials such as iron, zinc, calcium, carbon nano oxides, carbon nanotubes, silver, manganese, citric acid coated cesium oxides, magnesium, zinc oxides, carbon nano tubes, copper oxides and so on. Weretried on different crops and resulted in increase in productivity of crops.

Applying the nanotechnology in animal production sector:

As we know animal production consists of multiple sections. Dairy sector is the major important sector in agriculture. Cattle, yak, camel, goat, sheep etc. comes under diary. The next sector in animal production is meat, poultry, beef and goat meat comes under this sector. Fisheries are the next sector in animal production, this sector is divided into two sectors, and they are ornamental and food. The last sector in animal production is insects. Lac and silkworm (has commercial significance) comes under insect sector. With the help of Nanotechnology nutraceuticals are supplied to the animals as food and feed additives at nanoscale levels. These nutraceuticals are very important to animals as vitamins, minerals, nutrients etc. are necessary for the quality production. With nanotechnology drugs are delivered at targeted site. Generally antibiotics are delivered; this is called as site directed delivery of antibiotics. Metal nanoparticles are conjugated with polymers and the nutrients are delivered. With nanotechnology, biocides which are antimicrobial are applied in animal production. Using nanotechnology diagnostic tools are applied. diagnostic tools are of two types i.e. magnetic metal nanoparticles for MRI and florescent probes. Reproductive aids are done using nanotechnology. This deals with purification of sperm through the removal of damaged spermatozoa by using surface markers which are recognized by nanoparticle bound antibodies or lections (carbohydrate binding proteins). Molecular biology agents are applied by using nanotechnology in veterinary medicine which includes nanoparticle based gene delivery, gene transfer, DNA transduction etc.with nanotechnology increase in milk production, increase in biomass, increase the quality and quantity of eggs and many more are achieved.

Using Nanotechnology in pests and disease management:

Now a day's use of pesticides, fungicides and herbicides is the most effective and cheapest way in controlling diseases and pests, whereas use of biological control methods is expensive. Excessive use of pesticides has many adverse effects on human health, pollinating insects and domestic animals. When these materials enter into the soil and water, either proportionally or inversely they effect the ecosystem. Use of nanotechnology is the effective solution for this problem. The nanomaterials are given to the specific part of the plant which are affected by the diseases or pest. The nanoparticles have the power of self-regulation which means only the required amount will be delivered do the plant tissues. Nanotechnology reduces environmental pollution with the usage of nanoparticles and nanocrystals by producing chemical fertilizers and pesticide which is having the power to control the delivery and absorption. This method is the most effective and environmental friendly, by using nano crystals pesticides are produced with greater efficiency for application of lower dose. In most of the cases pesticides are applied for precautionary a purpose which leads to the residual toxicity and environmental hazards, if pesticides are applied after the occurrence of disease symptoms it results in loss of some crops. Viral diseases are very difficult to control if once they have started showing symptoms because it is very difficult to find the exact stage of viral DNA replication. Nano based viral diagnostics have been developed in order to determine the same strain of virus and the exact stage of application to lock/ prevent the disease. Biomarkers have also been developed which indicate the accurate stage of diseases.

Nanoparticles in appropriate concentrations can be utilised successfully for the controlling several plant diseases may occurred due to pathogens.

Nano silver: almost all Nano silversare the deliberate nanoparticle for bio system. It shows the broad-spectrum bactericidal as well as anti-microbial effects. Silver nanoparticles have more surface atom fractions, have wide surface area and also have more impact of anti-microbial effect as compared to bulk silver. It is also an effective Antifungal when it used as colloidal Nano silver which ranges nearly 1.5nm diameter. This is also effective against powdery mildew caused by SphaerothecapannosaVarrosae. Disease like Powdery mildew which spreads over wide range in both green house as well as outdoor roses, it also causes curling of leaf, early leaf defoliation, distortion and reduced the flowering. Nano silver acts as stabilizer as well as reducing agent, it is highly stable and easily spread over aqueous solution. It also removes undesirable microorganisms in ligneous soil and in hydroponics. This is used as foliar spray in order to prevent the fungal growth, olds and also much plant disease. Silver magnificently stimulate the plant growth.

Usage of nanotechnology at food industry:

Oxygen is the one of the most problem in packaging of food, because it causes food discoloration and food spoilage. With the help of nanotechnology new plastic has been developed for food packaging by food industry, for developing these plastic nanoparticles have been used. These nanoparticles get arranged as a zigzag over the new plastic and act as barrier by preventing the penetration of oxygen. Recently nano coatings have been developed and fruits are coated completely, this prevents the fruit shrinkage and fruit weight loss. Smart packaging to increase in shelf-life of the products is the goal of many companies, such packaging repairs the holes if present, can tolerate the fluctuations in environmental conditions and if the food is contaminated it can be easily identified. Nanotechnology has provided solutions for all these problems with developing the antibacterial and antifungal properties, improving the heat stress tolerance and mechanical stress tolerance, enhancing the barrier properties and it can sense the biological and biochemical changes. Ethelene absorbent is one of the most important materials produced by nanotechnology. This ethylene absorbent Nanomaterials absorbs the ethylene gas produced by the fruits and increases the long life of fruits. To observe the quality of agriculture products nano barcodes and nano processing is also used. By using biosensors we can identify if the food contains a large concentration of bacteria this gives a signal indicating that the food is unsafe.

Table 1. Some important breakthroughs of Nanotech. in Agriculture

Product	Application	Institution
Nanocides	Encapsulated Pesticides for controlled release in Nanotech. Emulsions of Nano for higher efficiency	BASF, Ludwigshafen, Germany Syngenta, Greensboro, NC, USA
Buckyball fertilizer	Ammonium from buckyballs	Kyoto University, Kyoto, Japan
Food packaging	Airtight plastic packaging done with silicate nanoparticles	Bayer AG, Leverkusen, Germany
Nanoparticles	Adhesion-specific Nano particles for removing Campylobacter jejuni in poultry	Clemson University, Clemson, SC, USA
Use of agriculture waste	Nanofibers from cotton waste to enhance strength of clothing	Cornell University, Ithaca, NY, USA
Precision farming	Nano sensors attached to GPS (global positioning system) tracking unit to observe soil conditions and crop growth in real time.	U.S. Department of Agriculture at Washington, DC in United states of America
Nano sensors	Pathogen detection Spread of Contamination in packaged food	Cornell University, Vevey, Switzerland Nestle, Kraft, Chicago, USA
Livestock and fisheries	Nano veterinary medicine (nanoparticles, buckyballs, dendrimers, nano capsules for drug delivery, nano vaccines; smart herds, cleaning fish ponds (Nano check and feed)	Cornell University Nano Vic, Dingley, Australia

Application of nanotechnology in agronomy:

In recent days precision farming is more preferred for farm management. By using nano sensors we can determine how much dose of fertilizer and chemical pesticides needed to be applied in a very little area of farm, therefore, by using Nano sensors the input can be optimized and increase in economic efficiency is obtained. Farmers are benefited with nano sensors as it ensures timely needs and control of plants timely. Wise use of natural resources of Agriculture like nutrients, chemicals and water through precision farming can be done using Nano sensors and Nano based smart delivery systems. To detect the evidence of stress such as drought and to detect pests in crops by farm managers Nano particles and GPS (global positioning systems) with imaging the fields using satellite are useful. Irrigation level and pesticides applications are controlled automatically if the drought or pest are detected. Nano sensors can detect the plant virus present in the field and the concentrations of soil nutrients. Now a days encapsulated nano slow release fertilizers have become a trend as they ensure slow and complete release of the fertilizer and also they ensure to minimize environmental pollution. Genetic content/makeup of the crop plants are modified by

using nanotechnology for the improvement of crop plants.

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