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Review Article

Recent Nanotechnological Advancement in Sustainable Agriculture

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Abstract

Due to increased use of fertilizers and chemicals causes environmental pollution and it can be reduced by using nano-based formulations. As nanofertilizers reduce the loss of nutrients to the atmosphere by delivering the nutrients whenever required and in a sustained manner, nanopesticides are also very helpful in controlling pests as they release toxins and kill the pests whenever it attacks the plant. Both nanofertilizers and nanopesticide help in reducing the days and dosage of the treatment. Nano-fertilizers are gradually been used as alternatives to conventional fertilizers and reduce pollution of soil and water by different agrochemicals. Nano-fertilizers release nutrients in slow and sustained manner and thereby reduce the loss of nutrients and enhance the nutrient use efficiency. In traditional pest control methods, producers excessively use pesticides, which pose a significant economic burden. Although there are some benefits of pesticide use, it can cause major problems in terms of environment, animal and human health due to potential toxicity (chromosome abnormalities, inhibition of erythrocyte function, enzyme inhibition, water pollution, etc.). Nanotechnological formulations can help to decrease toxic effects on non-target organisms, and develop physicochemical stability also prohibit degradation of the active agent by microorganisms. Nanotechnology also used in water purification techniques, water purification using nanotechnology utilizes nanosized materials such as carbon nanotubes and alumina fibers for nanofiltration, and it also utilizes the nanosized pores in zeolite filtration membranes and nanocatalysts. Nanosensors, such as those based on titanium oxide nanowires or palladium nanoparticles are used for the analytical detection of contaminants in water samples.

Keywords: Sustainable Agriculture; Nano Application; Slow Release Fertilizers; Plant Protection; Nanosensors; Carbon Nanotubes

Abbreviations

NUE: Nutrient Use Efficiency; SRP: Slow Release Profile; CRP Control Release Profile; NT: Nanotechnology; SNP: Silver Nanoparcticle; TEM: Transmission Electron Microscopy; SEM: Scanning Electron Microscopy; DLS: Dynamic Light Scattering; NPs: Nanoparticles; SNP: Silver Nanoparticles; ANP: Aluminum Oxide; PHSNs: Porous Hollow Silica Nanoparticles; XRD: X ray Diffraction.

Introduction to Nanotechnology

A Nanometer could be a unit of length within the system of weights and measures, adequate one billionth of a meter (10^{-9}). Technology is that the creating, usage, and information of tools, machines and techniques, so as to unravel a tangle or perform a particular perform. The engineering science plays a crucial role within the productivity through management of nutrients further because it also can monitor the water quality and pesticides for property development of agriculture. Properties (other than size) of NPs have the influence on toxicity embrace chemical composition, shape, surface structure, surface charge, behaviour, the extent of particle aggregation (clumping) or disaggregation, etc. could accompany built NPs. For this reason, even nanomaterial of identical chemical composition that has totally different sizes or shapes will exhibit their different toxicity. The implication of engineering science analysis within the agricultural sector has become to key issue for property developments. Within the agri-food areas pertinent applications of nanotubes, fullerenes, biosensors, controlled delivery systems, nanofiltration, etc. were discovered. This technology was evidenced to be nearly pretty much as good in resources management of agricultural field, drug delivery mechanisms in plants and helps to require care of the fertility of the soil. Moreover, its being conjointly evaluated steady inside the employment of biomass and agricultural waste conjointly as in food process and food packaging systems conjointly as risk assessment. Recently, nanosensors are widely applied inside the agriculture because of their strengths and quick for environmental.

Figure 1: Various applications of Nanotechnology.

Top down

In top down approach Nano objects and materials are created by larger entities without bouncing its atomic reactions usually top down approach is practiced less as compared to the bottom up approach.

Figure 2: Top down Approach in Nanotechnology.

Solid-state techniques can also be used to create devices known as Nanoelectromechanical systems or NEMS, which are related to microelectromechanical systems or MEMS. MEMS became practical once they could be fabricated using modified semiconductor device fabrication technologies, normally used to make electronics.

Bottom up

In the bottom up approach different materials and devices are constructed from molecular components of their own. They chemically assemble themselves by recognizing the molecules of their own breed.

Examples of molecular self-assembly are Watson crick base pairing, nanolithography.

Figure 3: Bottom Approach in Nanotechnology.

Nanoparticles are used as a carrier system in Agriculture like, Nano fertilizers, Nano pesticides, Nano herbicides, etc.

Nanoparticles can be used as eco-friendly carrier systems for targeted delivery of loaded substancesto protect the degradation of payload molecules. It also provide desirable release characteristics such as slow and sustain release profile by reducing dose and prolonged delivery, and reduce toxicity in the environment and to humans (Figure 4).

Nanofertilizers

In agriculture, nanotechnology has practical implication in enhancement of food production, with increased nutritional value, quality and safety. Well-organized application of pesticides, fertilizers, herbicides and plant growth promotors are different tools to recover crop production. Skillful discharge of pesticides, herbicides and plant growth promotors can be attained through nanobased delivery. It has been reported that nanoparticles encapsulated with poly (epsilon-caprolactone) has been innovated recently as vector for atrazine [1]. The treatment of *Brassica juncea* treated with these encapsulated nanoparticles increased the herbicidal efficacy when compared with marketable atrazine. Similarly, other nanocarriers like silica NPs [2] and polymeric NPs [3] have also been designed for release system to use of pesticides in well controlled manner. These kinds of novel innovations are often termed as "Precision farming" which realize on crop production without disturbing natural resources [4] mainly, use of nanoencapsulation can reduce quantity of the herbicide, without affecting potency, which results in eco-friendly conditions. Further using recombinant DNA technology nanoparticle mediated gene or DNA transfer in plants was applied in creating insect-resistant varieties [5,6]. It has been reported that ZnO NPs are excellent sources of antifungal agents which can acts against *Fusarium graminearum*, *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus fumigatus* thus remarkably can be used as crop protective agent [7].

Figure 4: Broad application of Nanotechnology in Agriculture.

The designing of nanofertilizers proceed towards the innovative remedy for drastic economic fatalities. Nanofertilizers are having vital role in overcoming this nutrient loss and increasing nutrient uptake in crops and soil micrflora [8]. It has been reported that the use of other nanomaterials like carbon nano-onions [9] and chitosan NPs [10] assist in enhancing crop production and quality. It is predicted that these newly designed nanofertilizers will motivate and transform recent fertilizer manufacturing industries in the next decades.

Preetha and Balakrishnan., *et al*. [11] has reported in his previous studies that, Fertilizers play a pivotal role in enhancing agriculture production in India (35 to 40%). Chemicals are inorganic fertilizers formulated in appropriate concentration and combinations supply three main nutrients: nitrogen (N), (P) and potassium (K) for various crops. However, major part of these fertilizers is lost to environment though physical, chemical processes like leaching, volatilization, emission and cannot be absorbed by plants causing economic and resource losses.

To enhance the nutrient use efficiency, build up by nutrients in soils, nano-fertilizers are emerging as alternative approach. For controlled and sustained release of fertilizer and pesticides, nano-fertilizers are expected to be far more effective with the high surface area to volume ratio. The use of nano-fertilizers makes plant roots and microorganisms to take nutrient ions from solid phase of minerals easily and in a sustainable way.

Thus it enhances soil quality by decreasing toxic effects associated with the overdose application of fertilizer.

Nano-fertilizers are the encapsulated fertilizers in which NPK fertilizers are entrapped in nanoparticles. Slow release of nutrients in the environment could be achieved by coating and cementing of nano and sub nano-composites. It is reported that nano-composite based fertilizers consisting of N, P, K, micronutrients, mannose and amino acids has been developed that has increased the nitrogen uptake and utilization by grain crops.

Bio-degradable chitosan nanoparticles have also gain great attention as controlled release for NPK fertilizers due to their bio-absorbable and bactericidal nature

For example: Nano-zeolite can act as a potential carrier for developing smart delivery fertilizers. Zeolites are group of naturally occurring minerals and has honey comb like porous layered crystal structure with the ability to exchange ions and catalyze reactions. Being made up of networks of interconnected tunnels and cages, it can be uploaded with nutrients, i.e., N, P and K, combined with other slowly dissolving ingredients containing phosphorus, calcium and a complete suite of minor and trace nutrients. Thus, nano-zeolite acts as a reservoir for nutrients that releases "on demand.

A number of studies indicate that these slowly released nano-fertilizers improve grain yield and has proved to be safe for germination of cereals. Besides the delivery of primary nutrients, sulphur coated nano-fertilizers have gained much attention due to their potential role in releasing sulphur in sulphur deficient soils.

Nanoparticles can even pass through the plant and animal cell, which is the main clue through which nanotechnologists able to achieve the phenomena of delivering the required product at cellular level.

Materials and Methods

Various techniques used for characterization of nano-based formulations

TEM (Transmission Electron Microscopy)

It provides with the 3D measurements of nanoparticles. It allows the rotation of sample by a desired angle to obtain proper image. The quantitative measures of particle size, grain size, size distribution, size homogeneity, lattice type, morphological information, crystallographic details, chemical composition and parameters can obtain by transmission electron micrography. So, TEM is the best technique for characterization of the nanomaterials such as nanoparticles and nanocomposites.

SEM (Scanning Electron Microscopy)

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. It uses a high beam of electrons in a raster scan pattern imaging the surface of the sample. For such microscopy, the sample must be solid. It gives information regarding the surface structure of particle

DLS (Dynamic Light Scattering)

The principles of dynamic light scattering

The method of dynamic light scattering (DLS) is the most common measurement technique for particle size analysis in the nanometer range. It measures the time dependent fluctuation in scattering intensity to determine the translational diffusion coefficient, subsequently hydrodynamic diameter.

ZETA sizer (Malvern Master Sizer)

The Malvern Mastersizer uses the principles of static light scattering (SLS) and Mie theory to calculate the size of particles in a sample. The basic principle is that small particles will scatter light at large angles and large particles will scatter light at small angles, as shown in the diagram on the right.

Nanotechnological approach to enhance NUE

- Encapsulation of fertilizer with nanoparticles.
- Slow delivery.
- Smart delivery system.
- Nano-biosensor.

Encapsulation

Solanki., *et al*. [12] reported the packaging the fertilizers within a kind of tiny 'envelope' or 'shell'. Encapsulation, controlled release methods and entrapment of agrochemicals has revolutionized the use of nano-composite material for agricultural use. Nano-encapsulated chemicals possess following characteristics such as proper concentration with high solubility, stability and effectiveness, timely release in response to environmental stimuli, enhanced targeted activity and less eco-toxicity making production of crops higher and less injury to agricultural workers.

Nanoparticles within the 100 - 250 nm size range able to dissolve in water more effectively than existing ones due to their effective surface tension quality. Use of nano-emulsions can also be better choice in terms of application of uniform suspensions of pesticides or herbicidal agents (either water or oil-based) and contain nanoparticles in the range of 200 - 400 nm. Formulations in the form of gels, creams, liquids, etc. have been performed to assess the effectiveness of the sol-gel based nanomaterials.

Advantage of NPs

Slow delivery

SRP (Slow release profile)-related to their water solubility, microbial degradation and chemical hydrolysis. CRP (Control release profile) - soluble fertilizers coated with materials that limit the exposure of material to water and/or release the resultant nutrient to solution by diffusion. Coating and binding of nano and subnano composites are able to regulate the release of nutrients from the fertilizer capsule [13]. Jinghua (2004) showed application of a nano-composite having N, P, K, micronutrient, mannose and amino acids enhance uptake and use of nutrients by grain crops. Fertiliser incorporation into nanotubes makes it for slow and controlled release.

Smart delivery system

Smart delivery includes timely controlled, spatially targeted, self-regulated, pre-programmed, avoid biological barrier to successful targeting. In smart delivery system, a small sealed package carries the drug which opens up only when the desirable location or site of plant system is reached. A molecular-coded ‘address label’ on the outside of the package could allow the package to be delivered to the correct site in the body. Similarly, implanting nanoparticles in the plants could determine nutrient status in plants and take up suitable remedial measures before the malady causes yield reduction in crops. This system can significantly reduce the response-time to sense the problem in fie.

Nano-biosensor

Since recent times we are aware about positive insinuations of nanomaterials, mainly wireless nanosensors, which has been innovated to monitor various crop pests, insects and weeds along with, nutrient efficiency, and natural physiochemical prevailing in cultivable land. It has been observed narrowly that, these designed nanosensors can detect minute quantities of pesticides and herbicides, in food and agricultural crops. Such practices on these nanosensors help to remediate damage in crop productivity and improve crop production, including optimum application of nanopesticide, Nanoherbicides and nanofertilizer. Current studies proved showed that copper doped montmorillonite has been recommended for monitoring of Propineb (broad spectrum fungicide) in aquatic environment (both in fresh and salty water) [14]. In other reports also it has been proved that nanomaterials like graphene has been utilized for identification of pathogen in wastewater [15] and makes it suitable for drinking water [16]. Other nanomaterials like copper NPs [17] carbon nanotube gold NPs [18] and silver NPs [19] are still under designing to act as nanosensors for real-time monitoring of natural conditions including crop production and protection.

Nanobiosensors are devices that measure a biochemical or biological event using any electronic, optical, or magnetic technology through a compact probe. Current advances in nanotechnology and advanced fabrication technology in electronics intersect towards creating a new set of biosensors called nanobiosensors and have ushered in a new era of bio nanotechnology for disease diagnosis.

Under nutrient limitation, crops can secrete certain compounds into rhizosphere to enable biotic mineralization of N or P from SOM and P-associated with soil organic colloids. These root exudates can be considered as environmental signals that can be recognized by nanobiosensor and release of nutrient occurs that synchronise with the plant's need.

Figure 5: Depiction of the block diagram of a biosensor.

Nanoherbicides

Prasad., *et al*. [20] reported elimination of weeds can be achieved by destroying their seed banks in the soil and prevent them from germinating when weather and soil conditions become favourable for their growth is one of the most promising technology. Molecular characterization of underground plant parts for a new target domain and developing a receptor based herbicide molecule having specific binding property with nano-herbicide molecules like carbon nano-tubes capable of killing the viable and dormant underground propagates of weed seeds.

Target specific nano-encapsulated herbicide molecules are aimed for specific receptor in the roots of target weeds. When these molecules enter into system by forming association with receptor, get translocate into its parts and inhibit glycolysis of food reserves in root system thus making specific weed to starve for food and get killed.

Nanopesticides

Kah., *et al*. [21] reported that pesticides are substances or mixtures of substances widely used to eliminate and control the harmful organisms, causing significant economic losses in agricultural production. There are many regulatory restrictions placed on pesticides in agriculture today. Pesticides such as DDT, which have caused extreme environmental hazards, have increased public and regulatory awareness of the use of chemicals in farming, shifting the industry focus on to the use of integrated pest management systems, combining smarter and more targeted use of chemicals with granular monitoring of plant health. The plant pest affecting the cultured products causes serious losses by limiting the product yield. Secondary metabolites (alkaloids, phenolics and terpenoids) secreted by plant as self-preservation mechanism of nature provide defense and protective function against insect. In traditional pest control methods, producers excessively use pesticides, which pose significant economic burden. Although there are some benefits of pesticide use, it can cause major problems in terms of environment, animal and human health due to potential toxicity (chromosome abnormalities, inhibition of erythrocyte function, enzyme inhibition, water pollution, etc.).

Nanotechnological formulations can help to diminish out of favour toxic effects on non-target organisms, as well as develop physicochemical stability and prohibit degradation of the active agent by microorganisms. Nanotechnology allows companies to manipulate the properties of a carrier for controlled release of substances to be used as agricultural input through encapsulation or attaching to the nano material (adsorption, attachment, cross-linking, or chemical bonding etc.). In the nano-encapsulation technique, the nano-sized active pesticide compound is covered by a thin-walled shell as a protective layer. The main objective in the nano-encapsulation technique is the 'controlled release of the active compound', to increase the efficiency of the active substance and to reduce the amount of pesticide in order to protect the environment.

The aims of nano-pesticide formulations are generally similar to those of other pesticide formulations, these being (a) to increase the apparent solubility of poorly soluble active ingredient or (b) to release the active ingredient in a slow/targeted manner and/or protect the active ingredient against premature degradation.

Marketed under the name Karate ZEON is a quick release microencapsulation nano-pesticide formulation containing active compound, i.e., α-cyhalothrin which breaks open on contact with leaves. In contest, the encapsulated product “gutbuster” only bark open to release its content when it comes into contact with alternative environment such as stomach of certain insect.

S. No.	Nanoparticle	Usages in Agriculture	Reference’s
1.	Carbon Nanotube	Increase in root length of wheat seedlings and also utilized in water purification	Wang., *et al*. (2012), John-David R. Rocha., *et al.* [22]
2.	Zeolite	They could be used as fertilizers, stabilizers and chelators. Zeolites enable both inorganic and organic fertilizers to slowly release their nutrients	Perez-Caballero., *et al.* (2008).
3.	Titanium oxide	Has great pathogen disinfection efficiency	Yao., *et al*. (2009)
4.	Alumina oxide	Efficient pesticides at Nano scale	Saurabh Singh., *et al.* (2015)
5.	Nano silver particle	Antifungal effectiveness and Control of Various Plant Diseases	Moazzameh Ramezani., *et al.* (2019)
6.	Nano silicon	Antifungal activity and controlled powdery mildews of pumpkin	HJ Park*., et al.* [23]

Table 1: Different Elements used in Nanotechnology.

Use of nanotechnology in agriculture

Nano silver

Singh., *et al*. [24] reported nano silver is that the most studied and utilized nano particle for bio-system. It has long been known to possess strong inhibitory and bactericidal effects, a broad spectrum of antimicrobial activities, high area and high fraction of surface atoms, have high antimicrobial effect more adhesive on bacteria and fungus, hence are better fungicide. Studied the antifungal effectiveness of colloidal Nano silver (1.5 nm average diameter) solution against rose mildew caused by *Sphaerothecapannosa Var. rosae*. It is a really wide spread and customary disease of both green house and outdoor grown roses.

Double capsulized nano silver for this disease sprayed at large area of 3306 m^2 polluted by rose mildew. Two days after the spray quite 95% of rose mildew faded out. It eliminates unwanted microorganisms in planter soils and hydroponics systems. It is getting used as foliar spray to prevent fungi, moulds, rot and a number of other plant diseases. Moreover, silver is an excellent plant-growth stimulator.

Nano silicon

Silicon (Si) is known to be absorbed into plants to increase disease resistance and stress resistance. Aqueous silicate solution (it promotes the physiological activity and growth of plants and induces disease and stress resistance in plants) Porous hollow silica nanoparticles (PHSNs) loaded with validamycin.

Nano sized silica

New composition of nano-sized Silica Silver for control of various plant diseases consisted of nano-silver combined with silica molecules and water soluble polymer, prepared by exposing a solution including silver salt, silicate and water soluble polymer to radioactive rays. It showed antifungal activity and controlled powdery mildews of pumpkin at 0.3 ppm in both field and greenhouse tests.

Nano alumino silicate

Alumino-Silicate nanotubes sprayed on plant surfaces are easily picked up in insect hairs. Insects actively groom and consume pesticide-filled nanotubes. Biologically more active and relatively more environmentally safe pesticides.

Mesoporous Silica Nanoparticles can deliver DNA and chemicals into Plants thus, creating a powerful new tool for targeted delivery into plant cells. Developed porous, silica nanoparticles systems spherical in shape arrays of independent porous channels. The channels form a honeycomb-like structure unique "capping" strategy. Plant cells have rigid cell wall. Hence to penetrate it they had to modify the surface of the particle with a chemical coating. It has been successfully used to introduce DNA and chemicals in to Arabidopsis, tobacco and corn plants.

Perspectives on biosynthesized and bioinspired nanomaterials

An eco-friendly approach for green synthesis for design and development of nanomaterials is attracting the whole world. Various biological modes like bacteria, fungi, virus, and medicinal plants and their extracts have gained potent attention for their biosynthesis. The prime advantages by adapting such protocols are that these modes act as manufacturing host and can act as capping, stabilizing, and reducing agent so that toxicity of metallic nature will be reduced during the synthesis processes along with that biosynthesis often acquire ambient temperature and pressure, and neutral pH which assist to sustain the use of energy resources and hazardous chemicals. The most prominent key fact is that these designed nanomaterials are having wide range of therapeutic applications with reduced toxicity.

There are several reports on their biosynthesis. Jain., *et al*. [25] reported that extracellular proteins isolated from microbes have major role in stabilizing silver NPs. Further, scanty research reveals role of biomolecules isolated from these living resources act as capping agent in synthesis. Moreover, optimum temperature and pressure, and neutral pH are the major urge for biological systems. Moreover, surface functionalization is a common approach to design biocompatible nanomaterials and to simulate many bioprocesses in nature. Therefore, these biological modes are recommended provides natural environment to provide surface functionalization on nanomaterials however, there are some limitations in biosynthesis of nanoparticles like low yield and low manage production pathway. It is still point of consideration that the exact biological processes responsible for nanoparticles biosynthesis remain to be explicated. There are some scanty reports which suggest that various phytochemicals and biomolecules like amino acids, polysaccharides, proteins, vitamins, flavonoids and alkaloids are responsible for physiological mechanism like electron transport chain in metal reduction, capping and stabilizing but the pathway is still to be studied. Further, it is quite tedious to plan nanomaterials with proper implications, like shape and size. This is very crucial for designing nanomaterials in therapeutic uses, which requires morphological properties to have vital role as nanocarriers. Some studies reported that orange extract was used to design round spherical silver NPs, whereas pineapple extract synthesized nanoparticles with sharp corners [26].

It is point of interest to discuss about the application of bioinspired nanostructures in food and agriculture systems. Liang., *et al*. [27] recently reported bioinspired mussel avermectin NPs with strong grip to crop verdure to reduce the loss and prevented contamination to soils treated with pesticides. The biologically designed nanoparticles exhibited tremendous high retaining capacity of avermectin, for sustained release.

Various designed bioinspired nanoparticles

Moazzameh., *et al.* (2019) has reported that Silver nanoparticles (SNP), aluminium oxide (ANP), flowers of zinc and titanium oxide within the control of black weevil and grasserie disease in silkworm (*Bombyx mori*) caused by *Sitophilus oryzae* and baculovirus Bm NPV (*B. mori* nuclear polyhedrosis virus), respectively. Performed bioassay, during which prepared solid and liquid formulations of the above mentioned nanoparticles; later, applied these formulations on rice and kept during a plastic box with 20 adults of *S. oryzae* and observed the effects for 7 days.

It was reported that hydrophilic SNP was best on the primary day. On day 2, 90 infant mortality was obtained with SNP and ANP. After 7 days of exposure, 95 and 86 infant mortality were reported with hydrophilic and hydrophobic SNP and nearly 70 you look after the insects were killed when the rice was treated with lipophilic SNP. However, 100% mortality was observed in case of ANP. Similarly, in another bioassay carried for grasserie disease in silkworm (*B. mori*), a big decrease in viral load was reported when leaves of *B. mori* were treated with ethanolic suspension of hydrophobic alumino-silicate nanoparticles.

Copper nanoparticles in mixture glass powder showed efficient antimicrobial activity against gram-positive, gram-negative bacteria and fungi.

Nanotechnology in reducing agriculture wastes

Nanotechnology is also applied to reduce waste in agriculture, mainly in the cotton industry. When cotton is processed into fabric or garment, a number of the cellulose or the fibers are discarded as waste or used for low-value products like cotton balls, yarns and cotton batting. With the utilization of newly-developed solvents and a way called electrospinning, scientists produce 100 nanometer-diameter fibers which will be used as a fertilizer or pesticide absorbent. These high-performance absorbents allow targeted application at desired time and site.

Ethanol production from maize feedstocks has increased the worldwide price of maize within the past two years. Cellulosic feedstocks are now considered a viable option for biofuels production and nanotechnology also can enhance the performance of enzymes utilized in the conversion of cellulose into ethanol. Scientists are performing on nano-engineered enzymes which will allow simple and cost-effective conversion of cellulose from waste plant parts into ethanol.

Rice husk, a rice-milling by product are often used as a source of renewable energy. When rice husk is burned into thermal energy or biofuel, an outsized amount of high-quality nanosilica is produced which may be further utilized in making other materials like glass and concrete. Since there's endless source of rice husk, production of nanosilica through nanotechnology can alleviate the growing rice husk disposal concern.

Nanotechnology in tillage

Sharifnasab., *et al.* [28] reported mechanical tillage practices improve soil structure and increase porosity leading to better distribution of soil aggregates and eventually modify the physical properties of soil. Literature on the effect of NPs on the tilth and tillage is limited.

Use of nanomaterials increase soil pH and improve soil structure. Nanomaterials also reduce mobility, availability and toxicity of heavy metals besides reducing soil erosion. Nanoparticles in soil reduce cohesion and internal friction besides reducing the shear strength of the soil. Reduction in adhesion of soil particles allows easy crushing of lumps with less energy.

Nanotechnology in seed science

Manjunatha., *et al.* [29] reported seed production is a tedious process especially in wind pollinated crops. Detecting pollen load that will cause contamination is a sure method to ensure genetic purity.

Pollen flight is determined by air temperature, humidity, wind velocity and pollen production of the crop. Use of biosensors specific to contaminating pollen can help alert the possible contamination and reduces the contamination. The same method can also prevent the GM crops contaminating field crops. Novel genes are being incorporated into seeds and sold in the market. Tracking of old seeds could be done by nanobarcodes that are encodeable, machine readable, durable and sub-micron sized taggants.

Diseases spread through seeds and many times stored seeds are killed by pathogens. Nanocoating of seeds using elemental forms of Zn, Mn, Pa, Pt, Au, and Ag will not only protect the seeds but used in far less quantities than done today.

Seeds can also be imbibed with nano encapsulations with specific bacterial strain termed as smart seed. It will thus reduce seed rate, ensure seed rate and improved crop performance.

Smart seed can be programmed to germinate when adequate moisture is available that can be dispersed over a mountain range for reforestation. Coating seeds with nano membrane which senses the availability of water and allows seeds to imbibe only when time is right for germination, aerial broadcasting of seeds embedded with magnetic particle, detecting the moisture during storage to take appropriate measure to reduce the damage and use of bioanalytical nanosensors to determine ageing of seeds and some possible thrust of research.

Metal oxide and carbon nanotube can improve the germination of rainfed crops. Carbon nanotubes serve as new pores for water permeation by penetration of seed coat and act as a passage to channelise the water from the substrate into seeds. These processes facilitate germination which can be exploited in rainfed agricultural system.

Nano technology in water use

Over 75% of the Earth surface is covered in water 97.5% of this water is salt water, leaving only 2.5% as fresh water. Nearly 70% of that water is frozen within the icecaps of Antarctica and Greenland, most of the rest is present as soil moisture, or lies in deep underground aquifers as groundwater not accessible to human use. < 1% of the world's water (~0.007% of all water on earth) is accessible for direct human uses. This is the water found in lakes, rivers, reservoirs and people underground sources that are shallow enough to be tapped at a reasonable cost.

Nanotechnology-derived water filtration processes are much more efficient as compared to traditional techniques, as these solutions can be fabricated with features that can enhance the adsorption of materials from water.

For example, properties such as reactivity and pore volume, as well as both hydrophilic and hydrophobic interactions, can be manipulated at nano level in water treatment solutions to exhibit high performance at an affordable cost.

The impurities that nanotechnology can check depend upon the stage of purification of water to which the technique is applied. It are often used for removal of sediments, chemical effluents, charged particles, bacteria and other pathogens. They explain that toxic trace elements like arsenic, and viscous liquid impurities like oil also can be removed using nanotechnology.

Water purification using nanotechnology exploits nanoscopic materials like carbon nanotubes and alumina fibres for nanofiltration, it also utilizes the existence of nanoscopic pores in zeolite filtration membranes, as well as nanocatalysts and magnetic nanoparticles. Nanosensors, like those supported titanium dioxide nanowires or palladium nanoparticles are used for analytical detection of contaminants in water samples.

Nanotube filters

The nanotubes act as a sort of molecular filter, allowing smaller molecules (such as water) to undergo the tubes, while contaminants are overlarge to undergo, due to their electronic configuration. Smaller ions that might otherwise undergo also are blocked.

Carbon nanotube membranes can remove most sorts of water contaminants including turbidity, oil, bacteria, viruses and organic contaminants. Although their pores are significantly smaller carbon nanotubes have shown to possess an equal or a faster flow as compared to larger pores, possibly due to the graceful interior of the nanotubes. Nanofibrous alumina filters and other nanofiber materials also remove charged contaminants like viruses, bacteria, and organic and inorganic colloids at a faster rate than conventional filters. Nanotechnology-derived water filtration processes are far more efficient as compared to traditional techniques, as these solutions are often fabricated with features which will enhance the adsorption of materials from water.

For example, properties like reactivity and pore volume, also as both hydrophilic and hydrophobic interactions, are often manipulated at nano level in water treatment solutions to exhibit high performance at an affordable cost.

Nanoadsorption

Adsorption is a surface process wherein pollutants are adsorbed on a solid surface. Adsorption takes place in general by physical forces, but sometimes this can be attributed to weak chemical bonds. The efficiency of conventional adsorbents may be restricted by their surface area, and lack of selectivity.

Usually nanoadsorbents are used to remove inorganic and organic pollutants from water and wastewater. The unique properties of nanoadsorbents, such as small size, catalytic potential, high reactivity, large surface area, ease of separation, and large number of active sites. Carbon-based nanoadsorbents, metal-based (>99.5% purity) nanoadsorbents, polymeric nanoadsorbents, magnetic or non-magnet oxide composite, and zeolites are currently used nanoadsorent technologies in the treatment of water [30-43].

Conclusion

Nanotechnology revealed auspicious capacities to be broadly consumed in agriculture and food industry. The concrete solicitation of nanotechnology and marketing nanomaterials based product still to be elucidated, seeing the unfortunate competence to govern features and interface of materials at nanoscale, along with mysterious environmental effect and empty toxicity database. This sometimes creates constraints for marketing of novel nanomaterials based products. Since executing eco-friendly practices have been crucial for success in today's biotechnology business; bioinspired approach is becoming famous in biomedical implications. Though, in the recent era the research and development in bio-inspired nanomaterials for their application in food and agriculture industries are still limited. Many nano-based products relating innovative nanotechnology have been marketed globally. This is continuous arena for the manufacturer due to safety code control by legislative branch of a government which needs approval process easy.

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Conflicts of Interest

The authors declare no potential conflicts of interest.

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