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APPLICATION OF NANOTECHNOLOGY IN AGRICULTURE

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ABSTRACT

From approximately 3.6 percent in 1985–1995 to less than 2 percent in 1995–2005, India's agricultural growth has slowed. This is far below the agriculture sector's goal of 4% annual growth by 2020. Food grain production is the main source of worry. Nanotechnology (NT) has been recognized as a promising technology for revitalizing the agricultural and food industries, as well as improving the life of the poor. Nanotechnology may help a variety of industries, including health care, materials, textiles, information and communication technology (ITC), and energy. Nanotechnology is used in crop production, food processing and packaging, food security and water purification, environmental remediation, crop enhancement, and plant protection in the agricultural industry. Agricultural production may be increased by using nanomaterials to create genetically better animals and plants, site-specific medication and gene delivery at the cellular/molecular level in animals and plants, and Nano array-based genetic alteration in animals and plants under stress. Nanotechnology has the potential to improve disease resistance, plant growth, and nutrient utilization by allowing precise administration of agrochemicals.Nano encapsulated solutions demonstrate the capacity to utilize pesticides, insecticides, and herbicides more effectively and site-specifically in an environmentally benign and greener manner. It has been effectively utilized in postharvest to preserve the freshness, *quality, and shelf life of stored products while also avoiding disease outbreaks in a relatively safe manner. Nanomaterials are a relatively new technology in agriculture, and further study is needed. Nanotechnology's application in agriculture has social and ethical implications that must be addressed. The toxicity of nanomaterials must be assessed before they can be commercialized and used in the field.*

KEYWORDS: *Agriculture, Climate, Fertility, Nanotechnology Soil.*

1. INTRODUCTION

In the period 2004–2015, India's agricultural growth was 3.59 percent (Ministry of Finance, Government of India 2014), which is lower than the goal of 4% annual growth in the agricultural sector by 2020. Food grain production is the main source of worry. Annual per capita food grain output has decreased from 207 kg in 1991- 1995 to just 179 kg in 2014 (Ministry of Agriculture, Government of India 2017–2018), posing a threat to food and nutritional security. With limited water and land resources, focused agricultural development may be achieved through careful application of modern technology to increase per unit natural resource productivity and farm revenue[1].During the green revolution, potential yields and agricultural earnings were multiplied by utilizing short-duration modified high-yielding cultivars, extensive fertilizer usage, irrigation, and pesticides, while failing to utilize natural resources sustainably and efficiently. Farm production and earnings have been steadily declining in recent years. Stabilization of agricultural output is essential to sustain overall national growth, since agriculture is the source of livelihood for 60% of India's people.

Degradation of natural resources such as soil, climate, and water hastens the issues[2]. “Technology fatigue” is a term used to describe the tough condition in Indian agriculture. Focusing on innovations that may improve agricultural output, resource usage efficiency, and product quality is the need of the hour to overcome "technology weariness."Nanotechnology (NT) has been recognized as one of the promising technologies that may revitalize the agricultural and food industries and enhance the life of impoverished people. Nanotechnology is one of six "Key Enabling Technologies" recognized by the European Commission as having a significant role to play in the long-term development of many sectors (EC 2012). Norio Taniguchi coined the phrase "nanotechnology" in 1974. Nanotechnology is a field of science concerned with the study of materials at nanoscale scales (1–100 nm) (US EPA). Individual atoms, molecules, and molecular clusters are manipulated into new structures with new or completely different characteristics. At the nanoscale level, it includes a variety of applications such as the construction, control, and structuring of devices and materials of different natures such as chemical, physical, and biological. In 2001, the US Federal Government launched the National Nanotechnology Initiative (NNI) to promote nanotechnology[3].

Nanotechnology, according to the NNI, is the reorganization of matter with at least one dimension ranging from 1 to 100 nanometers. In general, the novel physical and/or chemical characteristics of nanoscale devices and materials offer significant roles in health, electronics, biotechnology, energy, and materials science. Nanotechnology, as a tool, can address the world's most pressing water, energy, health, agricultural, and biodiversity (WEHAB) issues. The United Nations Johannesburg Summit on Sustainable Development in 2002 highlighted these five key topics. According to a UN survey, increasing agricultural production via nanotechnology in poor countries is the second most significant factor in attaining Millennium Development Goals, behind energy conversion and storage. Water treatment is the third most important use of nanotechnology. However, nanotechnology's use in the agricultural sector and food systems is still in its early stages both globally and in India, and its final success will be determined by stakeholder acceptability. The use of nanotechnology in agriculture necessitates the development of efficient regulatory and governance processes and systems involving all groups of stakeholders. As a result, nanotechnology has the potential to bring about a much-needed second green revolution in India's agricultural sector, with a focus on sustainable output. The following sections go through the many uses of nanotechnology in depth.

Agriculture benefits from many technical advances like as hybrid varieties, synthetic fertilizers, and pesticides throughout time. Now, agricultural experts are recognizing that smart innovation, such as nanotechnology, is critical for agricultural development in order to address global food security and climate change problems. Nanotechnology applications in agriculture have just recently gained prominence, although research on the subject began more than half a century ago. Nan materials are needed for increasing fertilization (or fertilizer) efficiency, yields, and reducing pesticide use; rapid and early pathogen and toxic chemical detection in food; smart pesticide and fertilizer delivery systems; smart food packaging and processing systems; and regulating agricultural food security. Agricultural productivity can be increased by using nanomaterial-induced genetically improved animals and plants, site-specific drug and gene delivery of molecules at the cellular/molecular level in animals and plants, and nano-array-based genetic modification in animals and plants under stress. Existing contaminants may be degraded and reduced using nanofilters or nanocatalysts, resulting in less pollution. Nanotechnology can be used in agriculture to make slow-release nanofertilizers for plant fertilizer; nanoparticles encapsulated pesticides for controlled and on-demand release; site-specific drug and nutrient delivery in fisheries and livestock; nanoparticles, Nano brushes, and Nano membranes for water and soil treatment; cleaning and maintenance of fishponds; and Nano sensors for a variety of applications.

1.1Application of Nanotechnology in Agriculture

- *Soil Fertility Management*: Fertilizers are needed to preserve soil fertility and produce high-quality food and crops, especially with the introduction of high-yielding, hybrid, and fertilizer responsive cultivars. Leaching, drifting, runoff water, evaporation, soil moisture-driven hydrolysis, and microbial and photolytic degradation are all losses caused by traditional fertilizer delivery techniques (such as spraying and broadcasting). As a result, relatively little concentration reaches the intended location. Conventionally applied fertilizers lose 40–70 percent nitrogen, 80–90 percent phosphorus, and 50–90 percent potassium in the environment, necessitating recurrent fertilizer and pesticide treatments. However, excessive fertilizer and pesticide usage pollutes the environment, degrades natural resources, develops pesticide resistance in pests and diseases, reduces soil microflora and nitrogen fixation, and produces pesticide bioaccumulation. As a result, the best use of chemical/synthetic fertilizer based on the nutritional needs of the crop and the least amount of pollution are critical. This may be accomplished by using Nano fertilizers. Nano fertilizers, also known as smart fertilizers, are nanomaterials (NMs) that provide single or multiple nutrients to plants, thereby improving crop development and yield, or those that attach, polymeric shell encapsulation, polymeric nanoparticles entrapment, and nutrient-rich nanoparticle synthesis. When coupled with Nano devices for synchronized release of N and P fertilizer, Nano fertilizers minimize undesired nutrient losses to the environment.

Nano fertilizers exhibit regulated chemical release, site-specific delivery, decreased toxicity, and improved nutrient absorption, Nano sized mineral micronutrient formulations can improve solubility as well as dispersion of micronutrients in soil, reduce absorption as well as fixation, improve bioavailability, which leads to increased NUE, and conserve fertilizer resources while complementing the better performance of conventional synthetic fertilizers (Liu and Lal 2015). A Nano fertilizer is a nanometre-sized product that delivers nutrients to particular target locations, improving nutrient usage efficiency (NUE) and reducing environmental degradation. Nutrients are encapsulated in nonporous materials, coated with thin film polymer, or supplied as nanoparticles or nanoemulsions in one of three ways: (a) encapsulated in nonporous materials, (b) coated with thin film polymer, or (c) delivered as nanoparticles or Nano emulsions (Rai et al. 2012). Because of the high surface tension, nanomaterial encapsulation on fertilizer bonds the material more firmly. High solubility, controlled and timed release, stability, efficacy, enhanced targeted action by providing appropriate concentration, and decreased toxicity with simple, safe distribution and disposal are all features of the fertilizer Nano formulation.

- *Environmental Remediation:* Pollutant degradation and sequestration are two types of environmental clean-up. The use of nanomaterials for remediation, i.e. Nano remediation, would be more efficient and cost-effective. Nano remediation (the use of nanoparticles for environmental remediation) may be used to clean ground and surface water, wastewater, soil, sediment, or other contaminants, as well as to reduce air pollution. Reactive nanomaterials are employed in Nano remediation to detoxify and convert contaminants. Reactive nanoparticles are injected into a polluted aquifer through an injection well in this procedure. The reactive nanoparticles are transported to the polluted location by groundwater. When nanoparticles come into touch with pollutants, they may bind to them, immobilize them, and breakdown them into less harmful and mobile molecules via adsorption or complexation. The cost of drilling and packing a well is high. Direct push wells are less expensive than drilled wells and are the most used technique for nano-iron clean-up. For site-specific areas, a nanoparticle slurry is also utilize[3]. Many reactive nanoparticles' performance has been assessed. For environmental remediation, nanoscale zeolites, noble metals, carbon nanotubes (CNT), metal oxides, and titanium dioxide are employed. Because of its large surface area and reaction rate, nanoscale zerovalent iron is the most appealing and often utilized material for environmental clean-up. with particle diameters ranging from 10 to 100 nm are injected into polluted sites to degrade them by forming a nanoparticle "wall" that cleans water as pollutants pass through it, or by employing mobile nanoparticles tiny enough to flow through soil pores. When nZVI is utilized to clean up a polluted location, it produces fewer harmful compounds throughout the cleanup process. In Nano remediation, bimetallic nanoparticles (BNP) are also utilized. BNP is made up of iron or other metal components that have been conjugated with metal catalysts such as platinum (Pt), nickel (Ni), gold (Au), and palladium. TCE (trichloroethane) elimination is usually done using palladium and iron BNPs[4]. Carbon nanotubes (CNTs) have recently become more popular due to their unique characteristics. Single walled carbon nanotubes (SWNT) and multiwall carbon nanotubes (MWNT) are two types of carbon nanotubes that are rolled into tubes (MWNTs).They are used to remove heavy metals such as Cr3+, Pb2+, and Zn2+, metalloids such as arsenic compounds and persistent organic pollutants (POPs) such as dioxin. The use of nanomaterials such as carbon nanotubes (CNTs) and titanium dioxide (TiO2) has the potential to purify, sterilize, and desalinate surface water. Heavy metals, organic pollutants, and pathogens are all common contaminants found in surface waters. Nanoparticles may be employed as sorbents or reactive agents in surface water treatment. Nanoparticles are also utilized in Nano filtration membranes. Air pollution can be controlled using nanoparticle-based filtering methods[5]. Nano filters in automobile tailpipes and industrial smokestacks will be able to separate pollutants and prevent their entrance into the atmosphere. Even at very low concentrations, Nano sensors can detect hazardous gas leaks.

- *Crop Improvement*: Scientists have been enticed by nanotechnology to think in new ways. It has been able to change the genetic composition of the crops, which would not have been feasible otherwise. A nanotech research project in Thailand sought to alter the atomic properties of indigenous rice varieties, including the well-known jasmine rice. It is a goal to eliminate the debate over genetically modified organisms (GMOs), since nanobiotechnology aids agriculture in avoiding the GMO debate and progressing to the next level - atomically modified organisms (AMOs).According to BIOTHAI, scientists from Chiang Mai University's nuclear physics lab have successfully used nanotechnology to change the colour of an indigenous rice cultivar.The cultivar is renowned for its purple stem, leaves, and grains, and the name "Kam" means "deep purple." The purple hue of the cultivar's stems and leaves has been transformed from purple to green thanks to nanotechnology. The research group's next goal, according to its scientists, is to deal with jasmine rice[6]. They want to develop a modified jasmine cultivar that is photo-insensitive, can be grown all year, and has smaller stems and superior grain colour. Mutation breeding is being used by Chiang Mai researchers. They're attempting to figure out the best way to get a nanoparticle through a plant's cell wall and membrane so that it can enter the cell and cause a specific change in the genetic makeup without interfering with other cell wall and membrane activities. Crop enhancement via mutation breeding and nuclear physics is a well-known technique, and the Vienna-based UN Food and Agriculture Organization/International Atomic Energy Agency program has made major contributions in this area since the technology's beginnings. Scientists have been using X-rays, beta rays, and gamma rays to alter the genetic composition of agricultural plants from the beginning[7].

- Crop Protection: Pesticides are used extensively throughout the globe to fight pests and diseases in order to satisfy the increasing population's food needs. Alternative methods of limiting pesticide usage are urgently needed. Only around 0.1 percent of pesticides reach target locations, and the rest is lost to the environment due to runoff, spray dispersion, off-target deposition, and photodegradation, resulting in higher environmental and application costs. Nanomaterials, one of the most recent advances in agricultural sciences, serve a critical role in plant protection due to their unique physical and chemical properties. The use of nanotechnology in plant pathology has provided fresh insights into crop protection[8]. Nanoparticles cling to the pathogen cell wall, causing deformity and eventually death because to increased energy transfer. Nanomaterials achieve two critical elements of disease management: first, efficiency with little environmental impact and decreased human health toxicity. Plant protection may be achieved via the controlled release of encapsulated pesticides against pests and pathogens, as well as the early detection of plant diseases and pollutants from pesticide residues using Nano sensors. Kuma and

Virage (2006) found that nanomaterials may be utilized to safely administer insecticides, herbicides, and fertilizers at lower dosages to cover large plant surfaces and thousands of plants[9]. Nano pesticide formulations assist in the slow release of less soluble active compounds by increasing their solubility.Pesticides are packed into nanoparticles and released in stages, depending on the requirement. Because nanoscale products are more reactive than bulk materials, crop protection is enhanced with a little quantity of noontides. The chemical is properly absorbed by plants after being Nano encapsulated for measured and effective release to a particular host plant for pest control. When creating a Nano product, the method by which nanomaterials are absorbed by plants and their subsequent mobility through plant tissues and organs is critical. The formulation changes depending on whether the active component is absorbed via the leaves or roots of the plant. The root can readily absorb noontides; however the nanomaterial will be absorbed more efficiently if it is ingested via the leaves[10].

1.2 Nanotechnology in Pesticides and Fertilizers

Agriculture that is both sustainable and profitable is required these days. It may be seen as presenting a long-term ecological strategy. Excessive tilling of the soil, which leads to erosion, and irrigation without proper drainage are two practices that may harm soil in the long run. Salinization will result as a result of this. This is to meet the requirements of humans for food, animal feed, and fibre. Long-term experiments are needed to demonstrate the impact of various methods on soil characteristics that are critical to long-term sustainability and to provide critical data for this goal. Nano-chemicals have emerged as potential agents for plant growth and pest control in the United States, according to a government body. Fertilizers are necessary for plant development. Nanomaterials that serve as fertilizers may have characteristics like crop enhancement and reduced environmental toxicity. Plants may provide an important pathway for bioaccumulation of contaminants into the food chain. The use of NPs for more effective and safe chemical usage in plants has been a recent breakthrough in agriculture. Several researchers have studied the effects of different NPs on plant growth and phytotoxicity, including magnetite (Fe3O4) nanoparticles and plant growth, alumina, zinc, and zinc oxide on seed germination and root growth of five higher plant species: radish, rape, lettuce, corn, and cucumber, silver nanoparticles and wheat seedling growth, sulfur nanoparticles on tomato, zinc oxi on tomato , and zinc oxi on Wheat growth and yield may be aided by silver nanoparticles. Wheat growth and production were significantly boosted by 25 ppm SNPs added to the soil. Zinc has long been regarded an important element for plant metabolic processes, despite the fact that it is only needed in minimal quantities. Zinc was discovered to have a key function in the control of reactive oxygen species and the protection of plant cells from oxidative stress. Zinc plays an essential role in the metabolic processes that lead to the production of chlorophyll and carbohydrates, as well as the synthesis of auxin or indole acetic acid (IAA) from tryptophan. Zn shortage may have an impact on agricultural production and product quality. Insecticide resistance in pest insects is becoming a bigger issue for agriculture and public health. Magnesium oxide is a common inorganic substance that has a wide range of applications, including adsorbents, fire retardants, improved ceramics, hazardous waste remediation, and photo electronic materials. As a result, different Mop synthesis methods and pathways have been described. Green techniques were used to make Mg OH, which included nontoxic neem leaf extract, Citrus lemon leaf extract, and acacia gum.

- *Pest control for plants:* Fusarium wilt is a devastating disease of tomato and lettuce in many regions owing to significant production losses, fungal survival in the soil for extended periods of time, and the development of resistant races. With the use of resistant cultivars and pesticides, the disease may be controlled to some degree. However, the emergence and development of new pathogenic races is a persistent issue, and chemical treatment is both costly and ineffective. In recent years, nanoparticles have been proposed as a potential option for controlling plant diseases. produced magnesium oxide nanoparticles and investigated the impact of various concentrations on the green peach aphid (GPA) in a greenhouse setting.

- *Potential for Nano insecticidal action:* Copper oxide nanoparticles may be made in a variety of ways, including precipitation and chemical reduction . Citrus lemon juice and carob leaves [are two examples of plant aqueous extracts that have been documented. Many researchers have developed various methods for synthesizing ZnONPs, including chemical, precipitation, hydrolysis in polar organic solvents, and microwave synthesis.

- *Antimicrobial activity:* Several nanomaterials, including silver nanoparticles, are employed as antibacterial agents in food packaging. This is due to its extensive usage. Titanium dioxide ($TiO2$), zinc oxide, silicon oxide ($SiO2$), magnesium oxide, gold, and silver are some of the other nanoparticles presently in use. Each has its own set of features and activities; for example, zinc nanocrystal has antibacterial and antifungal properties. Silver was utilized by NASA and the Russian Space Station to cleanse and sterilize water, silver zeolite, and silver. Gold has excellent antifungal and antibacterial properties against 150 different microorganisms, as well as great temperature stability and minimal volatility.

2. DISCUSSION

As a consequence of dangerous nanoparticles, researchers have a wide range of risk perceptions. Nanoparticles may enter the human body via eating, cutaneous exposure, and inhalation, and they can penetrate the circulation, blood–brain barrier, and digestive system owing to their high bioavailability. It's important to remember that nanoparticles have different chemical characteristics than their bulk equivalents while developing regulations. When it comes to agriculture, nanoparticles may help poisons penetrate deeper into the soil.Nanoparticles may bind with other contaminants due to their greater surface area. To identify possible dangers, possibilities of exposure, and the risks that nanomaterials pose to people and other animals, risk assessment is needed. There is a requirement to assess the degree of potential hazards and environmental consequences.Nanomaterials should be thoroughly described and evaluated for mammalian and ecological safety. Although many studies have found no toxic effect of nanoparticles on soil microbial community, interpretations about potential risk should be based on scientific evidence rather than speculations. They carry them through the soil, resulting in Nano-pollutants to be adsorbed and absorbed deeper and faster than normal. Furthermore, nanoparticles are often reactive and may accelerate physical or chemical interactions with contaminants, potentially resulting in the formation of new hazardous substances. It's still unclear if the various alternative methods are effective at the nanoscale, or how many have been validated for nanomaterials thus far. Before any regulatory action is implemented, several fundamental questions about the issue problem should be asked: is the current regulatory framework adequateIf not, where should the focus of effort for nanotechnology regulation be? As a result, appropriate risk assessment and safety measures must be implemented. Science-based policy choices will aid in the formulation of a suitable risk assessment methodology throughout this process. Science assists in making informed policy choices by providing risk and benefit information about a technology or a product produced from it.

3. CONCLUSION

Agriculture, food processing and packaging, food security and water purification, environmental remediation, crop development, and plant protection all benefit from nanotechnology. Nanotechnology has the potential to improve disease resistance, plant growth, and nutrient utilization by allowing precise administration of agrochemicals. Nano encapsulated solutions demonstrate the capacity to apply pesticides, insecticides, and herbicides more effectively and site-specifically in an environmentally benign, greener manner. It has been effectively utilized in postharvest to preserve the freshness, quality, and shelf life of stored products, as well as to prevent disease outbreaks in a relatively safe manner. Nanomaterials are a relatively new technology in agriculture, and further study is needed. Nanotechnology's application in agriculture has social and ethical implications that must be addressed. The toxicity of nanomaterials must be assessed before they can be commercialized and used in the field. Nanomaterials have the potential to harm the ecosystem, the environment, and human health. According to experts, the potential dangers associated with nanoparticles discharged into the environment are very hazy. Consumer and commercial goods discharge a large quantity of engineered nanoparticles into the environment as technology advances. The current critical limitation in agricultural use is production scale and cost. Nanomaterials will be mass-produced in large quantities, and their effective application in agriculture will drastically decrease costs. Nanomaterials' potential use in many agricultural applications necessitates further study into their synthesis, toxicity, and successful application in the field. There are still many opportunities to explore with new Nano products and methods in the area of agriculture.

Despite the potential benefits of nanotechnology, agricultural applications are limited in comparison to other industries. The academic sector is mainly responsible for agricultural success. For it to succeed on the ground, public opinion and appropriate regulatory mechanisms are essential. In order to evaluate safety, several regulatory agencies should be engaged. The proper labelling of Nano products may give a new technology a bad connotation. When consumers read labelling on Nano products, they may reject them. Some consumer preference surveys revealed a generally unfavourable public perception of nanotechnology. Agriculture remains a borderline area for nanotechnology, as pioneering agro-nanotech products struggle to find a market. This is due to high manufacturing costs of nanotechnology-based goods, which are needed in large quantities in the agriculture sector, unclear technological profitability, regulatory concerns, and public opinion. However, the research and development prospects are extremely promising, and the possibilities provided by nanotechnology in a variety of agricultural applications are being thoroughly investigated. In addition, nanotechnology is rapidly evolving in other fields. Information gained in other emerging areas, such as energy and packaging, may be used to agricultural purposes, or may have spillover effects. Precision farming becomes highly advanced and accurate when we use a synergistic approach that includes smart Nano sensors, wireless sensor networks with smart dust sensors, ambient intelligence and other technologies that help farmers make better decisions by providing precise information. The issue of enabling Nano sensor communication is yet unsolved. To overcome the difficulties and actualize this new paradigm, additional research on network size, energy harvesting, channel modelling, routing algorithm, and improved MAC protocol is required.

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