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Mini Review
Nanobiotechnology Advances in Medicine, Agriculture and Other Important Areas: Applications and Future Perspectives

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Abstract

Nanotechnology is one of the fascinating fields of interest for the researchers due to its swift action and the minimal size product requirement. Recent advancements in the technologies especially into nano-sized particles or materials manufacturing have led to the fabrication of nanomaterial of different sizes and shapes. The advantageous usage of metallic nanoparticles in agricultural ecosystems is not abundantly explored with limited scientific information available. Most of the studies are limited to laboratory conditions and only a few involved with the natural ecosystems. The Nano technological aspects into agricultural and biomedical sciences are found to be thriving in the nearing future. Researchers show much interest in the green synthesis of nanoparticles and beneficial effects in various fields. This mini review concisely describes the nanotechnology advancements in agriculture and biomedical applications which directly or indirectly linked to the human wellness. The scope of the applications of nanotechnology in the fields of agriculture and medicine is vast and yet to know clear understanding of the mechanisms.

Key words: Nanotechnology, agriculture, cancer, wellness, medicine, modern advancements

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INTRODUCTION

Nanotechnology deals with the materials with a particle size in the range of 1-100 nm. A nanometer (nm) is equals to one-billionth of a meter. Nanotechnology is one of the advanced areas which do miracles in combination with biotechnology, medicine, agriculture, food industry etc[1]. The expansion of nanotechnology into different areas of biological sciences, agricultural sciences, life sciences and medicine has noticeably showed the potential efficacy towards the agricultural benefits and human wellness. At present the nanotechnology and its applications are emerged with various types of fields including food, agriculture, information technology, robotics, Aerospace, energy, environment, biotechnology, medicine, healthcare, textiles etc. (Fig. 1). Nanotechnology is one of the thriving areas which show the advancements as well as impact on various factors including the global economy, new innovations and human lives as well[2]. The synthesis, physicochemical properties, size, shape, biological applications of the nanoparticles synthesized from different sources vary and constantly depends on the surface properties[3]. At present, the exact mechanism of action and the role of green synthesized nanoparticles and their associated biological potential is one of the keen issues to understand scientifically. Thus, a comprehensive and thorough characterization which includes the size, shape, surface characterization is suggested for synthesized nanoparticles or nanomaterials. The characterization of the nanoparticles can be measured and controlled by several approaches such as UV-Vis spectrophotometer, X-ray diffractometer (XRD), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), Dynamic light scattering (DLS), Zeta potential analyzer etc.

Metallic nanoparticles have significant benefits in various fields with the nanotechnology based products. Several types of metallic nanoparticles including silver, gold, zinc, titanium, silica and others are reported to have potential benefits in agriculture, medicine and ultimately to the human wellness[4]. The combination of the metallic nanoparticles which involves with the bimetallic nanoparticles also projected to have biological efficacies. Among the metallic and bimetallic nanoparticles, silver nanoparticles (AgNPs) have been reported to have significant potential benefits. At present the researchers focus more towards the synthesis of nanoparticles using plant material. Numerous studies reported the synthesis of silver nanoparticles through various methods including physical, chemical, microbial as well as biological methods. One of the major disadvantages with the chemical synthesis

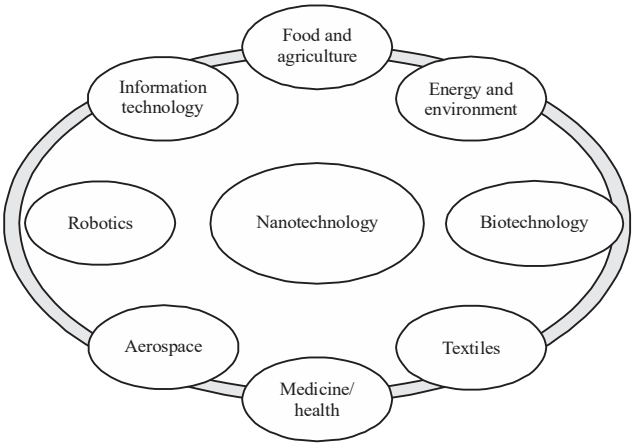

Fig. 1: Applications of nanotechnology: A smart art representation

of silver nanoparticles may be toxic due to the presence of the toxic chemicals which can pollute the environment, harmful to living creatures when applied in the real life scenario[5]. Therefore, there is a serious requirement to improve eco-friendly synthesis of AgNPs through biological approaches. Medicinal plants and biological sources play an important role in the synthesis of nanoparticles using metallic ions[6]. Phytosynthesis of AgNPs using different types of plant materials has several advantages when compare to the nanoparticle synthesis through microbial approach. Hence, the researchers' consideration towards the synthesis of metallic nanoparticles using plants and their parts is escalating day to day. Several studies reported the synthesis and biological potential of AgNPs using various plant extracts. Formation of nanoparticles depends on various factors; some of the reports claimed that the proteins from the plant extracts react with the silver ions to form the silver nanoparticles through the reduction process[7]. Hence, in the present work, various approaches for the synthesis of nanoparticles and their benefits in the fields of agriculture, biomedicine and finally to the human wellness are discussed.

SYNTHESIS METHODS

Different approaches are in use to synthesis the metallic nanoparticles including physical, chemical and biological approaches. Physical approaches are advantageous methods to synthesize the nanoparticles but the major disadvantage is their energy consumption levels. In chemical approach, the synthesis of metallic nanoparticles may have toxic effects and other undesired reactions. In biological approaches, the microbial synthesis of nanoparticles using different types of

microorganisms such as bacteria, fungi, yeasts and plant mediated synthesis of nanoparticles play an important role in possessing the potential activities against various types of microorganisms and diseases such as cancers, dermal diseases, diabetes, etc[8]. Overall, the synthesis of metallic nanoparticles using different plant extracts is the extensively used approach due to its eco-friendly, cost effective when compare to the other methods[9].

Advantages of green synthesis of nanoparticles: At present "green" method has gained much attention from the scientists and researchers especially in the synthesis of nanoparticles due to disadvantages of using conventional physical and chemical methods. Moreover the synthesis of nanoparticles using chemical methods is expensive and even toxic. Green chemistry is one of the focused fields which lessen the risk from the pollution at source level as the reagents used in the reaction are ecofriendly[10]. The quick synthesis of nanoparticles can be achieved through physical and chemical methods, but due to the undesired disadvantages, the biogenic green synthesized nanoparticles are safer and environmental friendly[11].

NANOTECHNOLOGY: ITS APPLICATIONS IN AGRICULTURE

Plant germination: In recent years, several scientists and researchers focus on the biological applications of green synthesized nanoparticles. Agriculture is one of the major fields where nanotechnology plays an important role in possessing the potential activities[12]. Plant germination is one of the key aspects in agriculture. The germination of the seeds is faster and success rate is higher using nanotechnology or nanomaterials or nanoparticles when compare to the normal conditions. Carbon nanotubes were reported to have potential penetration capacity into the tomato seeds and escalate their germination[13]. The germination was found to be significantly greater in the seeds treated with carbon nanotubes when compared to the normal media. The study revealed that the carbon nanotubes were capable to penetrate into the thick seed coat and support the water intake inside the seeds, which can positively affect the seed germination and growth of tomato seedlings as well. A study by Zheng *et al.*[14] reported the potential efficacy of titanium oxide (TiO_2) nanoparticles and non-titanium nanoparticles on spinach seeds germination for 30 days. The study compared the results between TiO_2 nanoparticles and TiO_2 mixture. The study revealed that the seeds treated with TiO_2 nanoparticles shown betterment in the production including the dry weight, rate in the photosynthesis and also elevated levels in the formation of chlorophyll. The main reason for the augmented germination and growth rate might have been the photo-sterilization and photo-generation of active oxygen like superoxide and hydroxide anions by nano-TiO_2 that can intensify the seed stress resistance and stimulate capsule penetration for intake of water and oxygen required for rapid germination[14].

Plant production: Nano pesticides involve with nano sized particles of pesticide active constituents with significant pesticide properties. Nanomaterials and nanoparticles are usually with large surface area and thereby offer the potential benefits[15]. In the same manner, the nano pesticides also provide huge surface area and therefore improved activity. Nano emulsions, nano cages, nano containers and nano encapsulates are some of the important nano pesticide delivery techniques in the field of agriculture which can provide significant beneficial effects than the normal pesticides[16]. The nanoparticles or nano formulations impact on plants growth and production is at significant levels[17]. The nano formulations degrade quicker in soil and gradually at low levels in plants below the regulatory standards in crops.

Agricultural water quality management (WQM): The quality of water in the agriculture systems has become one of the major challenges due to the increase of industrial wastes and unwanted releases by humans. At present, the fresh water for the regular use and industrial applications such as agriculture is one of the most important challenges across the globe[18]. In the coming future, it has been estimated that the average water supply per person will be decreased in such a way that it will result in the preventable premature death of millions of people. Generally, agriculture needs huge amounts of water to survive and gain the prospective outcomes. The water is polluted continuously through various factors such as industrial wastes, pesticides, chemicals etc. This finally results in the production of massive waste water amounts. The waste water needs to be treated in order to use them in different fields such as agriculture, animal protection as well as human consumption and the untreated waste water leads to bacterial resistance and finally problematic to the human beings[19]. Various types of physical, chemical and biological methods are available to treat the waste water. Numerous factors need to be considered in treating the waste water such as quality of the water, amount of water, reusability, specifically water safety etc. One of the emerging fields in the modern research, nanotechnology plays an important role in showering several beneficial ways to treat the waste water[20]. Latest progresses in nanotechnology provide catapulting prospects to develop next-generation water supply systems. Nanotechnology and

its advancements are projected to deliver great performance, cost effective treatments for normal water as well as wastewater[21,22].

Impact on the environment: The impact of nanoparticles on environment is also one of the key areas to be considered. Nanoparticles play dual role as direct and indirect role in the environmental aspects. The research on silver nanoparticles and their benefits towards various fields is thriving and some of the researchers raise the issue on toxicity. The toxicity of silver nanoparticles on environment is always depends on the composition, concentration and also the form of silver and when considering the soil toxicity, it depends on the different types of properties of the soils too[23]. The nanoparticles once released into the environment, they spread into various directions, which cannot show much impact on the environment due to the alteration in their structure, property and also mobility[24].

NANOTECHNOLOGY: ITS APPLICATIONS IN BIOMEDICINE

The metallic nanoparticles specifically silver nanoparticles play an important role in antibacterial, antifungal and other biomedical properties[25]. The biological synthesized silver nanoparticles using plant material has been an established practice due to their significant potentials. The biomedical benefits of nanoparticles are also applied into various diseases such as diabetes, cancers etc.

AgNPs as antimicrobial agents: The prospective usage of engineered silver nanoparticles (AgNPs) has got tremendous attention in various fields of medical applications. Antimicrobial activity is one of the well-known biological efficacies of metallic nanoparticles. Especially the biogenic green synthesized metallic nanoparticles have become one of the most desirable research interests due to their swift and great potential[26]. Numerous medicinal plants have been used to synthesize the nanoparticles and reported their antimicrobial activity. The silver ions are toxic to the different types of microorganisms when compare to the other metals. They directly or indirectly act on the microbial membranes and other types of cells. The mechanism of action is reported to have through different means including the membrane disruption, production of reactive oxygen species which can disturb the growth of the microorganism and finally leads to the death. The metallic nanoparticles specifically silver nanoparticles have been found to have potential efficacy against different types of viruses including Tacaribe virus (TCRV), influenza A/H1N1 virus, human immunodeficiency virus (HIV-1), recombinant respiratory syncytial virus (RSV), hepatitis B virus (HBV), murine norovirus (MNV)-1 and monkey pox virus[27]. Recent studies on the potential effects of silver nanoparticles on pathogenic viruses such as FX174 and MNV reported that the usage of nanoparticles could inactivate the pathogenic viruses at the significant levels and also reduced the release percentage into the environment. Various types of metallic and bimetallic nanoparticles against different types of microorganisms have been shown in the Table 1.

Potential therapeutic applications of AgNPs in cancer: Metallic nanoparticles are found to be as promising antitumor agents. Generally, the main use of the nanoparticles in the therapeutic purposes is to reduce the size or concentration or dose of the drug[64]. Even at minimal concentrations, the silver nanoparticles are capable of causing damage in the DNA and also aberrations in the chromosomes without cytotoxic effects[65]. Several studies have been reported that the positive responses and beneficial efficacies of silver nanoparticles when treated with the cancerous cells. The incorporated silver nanoparticles not only submissively intermingle with the cells, but also keenly facilitate the molecular progressions to control the cell functions[66]. Leukemia is one of the cancers which is a combination of different cancers which generally initiates in bone marrow and leads to the extraordinary volumes of unusual white blood cells. Several investigators have reported that AgNPs show cytotoxic effect against leukemic cells including Jurkat, THP-1 and K562 cells. Another recent study reported[67], that the silver nanoparticles induce cell death by producing reactive oxygen species, activation of caspase 3 and also DNA destruction[67]. Studies have been reported the potential effects of silver nanoparticles on different types of cancerous cell lines such as hepatic carcinoma cells HepG2, human alveolar cell line A549 cells[68], H157 squamous cell lung carcinoma cells[69], melanoma[70] cell lines HT144 etc. The mechanism of action usually demonstrates that the metallic nanoparticles disrupts the mitochondrial membranes by producing the ROS and directs to the cell death[71]. It is also one of the well-known facts that angiogenesis play a vital role in various diseases including cancer.

Nanoparticles in diabetes: Nanotechnologies at various levels play a vital role in the therapeutic efficacy in monitoring diabetes. Different types of nanotechnology-based methods have been developed, including layer-by-layer (LBL) technique, smart tattoos, carbon nanotubes and quantum dots (QDs) etc.[72,73]. Several attempts have been made in the field of nano medicine to develop new techniques which

Table 1: List of metallic and bimetallic nanoparticles synthesized form medicinal plants and their antimicrobial efficacy

Name of the plant	Type of the metallic nanoparticle	Action	References
Acalypha indica	Silver nanoparticles	Antimicrobial activity against water borne pathogens such as *Escherichia coli* and *Vibrio anopar*	Krishnaraj *et al.*[28]
	Gold nanoparticles	Cytotoxic studies against human breast cancer *Escherichia coli*	Krishnaraj *et al.*[29]
	Copper oxide nanoparticles	*Pseudomonas fluorescens* and *Candida albicans*	Sivaraj *et al.*[30]
Azadirachta indica	Silver nanoparticles	Antimicrobial activity against *Escherichia coli*	Tripathi *et al.*[31]
	Silver nanoparticles	Mosquito vectors (*Aedes aegypti* and *Culex quinquefasciatus*) control	Poopathi *et al.*[32]
Boswellia ovalifoliolata Bal.	Silver nanoparticles	Antimicrobial activity	Savithramma *et al.*[33]
Catharanthus roseus	Silver nanoparticles	Antiplasmodial activity against *Plasmodium falciparum*	Ponarulselvam *et al.*[34]
	Silver nanoparticles	Antimicrobial activity	Kotakadi *et al.*[35]
Carica papaya	Silver nanoparticles	Antimicrobial activity	Jain *et al.*[36]
Cinnamon zeylanicum	Silver nanoparticles	Antimicrobial activity	Sathishkumar *et al.*[37]
Curcuma longa	Silver nanoparticles	Antimicrobial activity	Sathishkumar *et al.*[38]
		Antifungal activity	Singh *et al.*[39]
Curcumin	Silver nanoparticles	Antimicrobial activity	Bhawana *et al.*[40]
Datura metal	Silver nanoparticles	Antimicrobial activity	Nethradevi *et al.*[41]
Euphorbia hirta	Silver nanoparticles	Antibacterial activity	Elumalai *et al.*[42,43]
		Antifungal activity	Abubakar[44]
		Bacterial associated enteric activity	Priyadarshini *et al.*[45]
		Biolarvicidal and pupicidal activity	Annamalai *et al.*[46]
	Gold nanoparticles	Antimicrobial activity	
Ficus benghalensis	Silver nanoparticles	Antibacterial activity	Saxena *et al.*[47]
Garcinia mangostana	Silver nanoparticles	Antimicrobial activity	Veerasamy *et al.*[48]
Hemidesmus indicus	Silver nanoparticles	Antibacterial activity	Khanra *et al.*[49]
Impatiens glandulifera	Silver nanoparticles	Antibacterial activity	Devi *et al.*[50]
Mangifera indica	Silver nanoparticles	Antimicrobial activity	Sarsar *et al.*[51]
Nelumbo nucifera	Silver nanoparticles	Larvicidal activity against malaria and filariasis vectors	Santhoshkumar *et al.*[52]
Ocimum sanctum	Silver nanoparticles	Antimicrobial activity	Ramteke *et al.*[53]
Olea europaea	Silver nanoparticles	Antimicrobial activity	Awwad *et al.*[54]
Polyalthia longifolia	Silver nanoparticles	Antibacterial activity	Kaviya *et al.*[55]
Piper betle	Silver nanoparticles	Ecotoxicological studies on *Daphnia magna*	Rani and Rajasekharreddy[56]
Rhinacanthus nasutus	Silver nanoparticles	Antimicrobial activity	Pasupuleti *et al.*[57]
Sida acuta	Silver nanoparticles	Against *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti*	Veerakumar *et al.*[58]
Tinospora cordifolia	Silver nanoparticles	Pediculocidal and Larvicidal	Jayaseelan *et al.*[59]
Tinospora cordifolia	Silver nanoparticles	Antibacterial activity	Anuj and Ishnava[60]
Tribulus terrestris	Silver nanoparticles	Antimicrobial activity	Gopinath *et al.*[61]
Withania somnifera	Silver nanoparticles	Antimicrobial activity	Nagati *et al.*[62]
Zingiber officinale	Silver nanoparticles	Antimicrobial activity	Singh *et al.*[63]

Source: Rao *et al.*, 2015

conquer important position for the construction of nanomaterials that can be applied in different stages of the disease. However, very few techniques have been translated into clinical use. Overall, blood glucose monitoring and insulin delivery systems are two major improvements related to diabetes treatment that have been facilitated by nanotechnology[74].

CONCLUSION AND FUTURE RECOMMENDATIONS

Numerous applications of nanomaterials or nanoparticles or nanotechnology are in regular practice. The present work focused on few specific applications of nanomaterials in agriculture and biomedical applications which are useful for the human wellness. The applications of nanotechnology towards the agricultural sciences are abundant, but only few are discussed. Through the modern nano techniques, the swift plant germination and production can be achieved. The nanoparticles provide much protection against several types of insects and pests as well. This review also explains few benefits of the nanotechnology in the fields of the biomedicine including cancers, diabetes, microbial activities etc.

The current review describes about the prospective benefits of nanoparticles or nanotechnology for different agricultural and biomedical applications, more explorations and research is required to inflate the possibilities and methodologies in agriculture, biomedical sciences as well.

SIGNIFICANCE STATEMENT

The study sheds the light briefly on the advancements of nanotechnology and its applications in the field of medicine and agriculture, which can be beneficial for the future research especially to uncover the exact mechanism(s) of nanoparticles or nanotechnology or nanomaterials in various specialized areas of medicine, agriculture and engineering as well.

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