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Review article

The role of nanotechnology for improving crop production

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Abstract. Today, green nanotechnology has great importance due to the presence of different modes of restrictive action against various pathogens such as fungi and bacterial species. The use of nanomaterials has recently increased in agriculture and plant-tissue culture thanks to their unique different properties such as; magnetic, electrical, mechanical, optical, and chemical properties. Optimum use of iron increases protein content in the wheat grain. They also enhance plant growth by improving disease resistance and increase stability of the plants by anti-bending and deeper rooting of crops. It has been reported by many researchers that Nano-fertilizers significantly influenced the seed germination which demonstrated the effect of Nano fertilizers on seed and seed vigor. Chemical methods have been used for the synthesis of nanoparticles. Developing Nano-biotechnology is generating interests in research towards eco-friendly, cost effective and biological synthesis of nanoparticles. Nanoparticles systems have been combined into plant fungal disease controlpractices. Using nanoparticles as biosensors in plant disease diagnostics is also illustrated.

Key words: nanoparticle, nano-fertilizer, nanotechnology

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Introduction

Nowadays, environmental pollution caused by the use of chemicals and the unpredictable results of biological control have been widely investigated [1]. Nowadays, green nanotechnology has a great advantage due to the presence of different modes of inhibitory action against various pathogens such as fungal and bacterial species [2]. Nanotechnology is used in different stages of production such as processing, storage and plays an important role in the transportation of agricultural products.

This technology has great potential of transforming agriculture and food industry by applying new innovative methods such as precision farming methods, control release of agrochemicals and site target for delivery of different macromolecules needed for improving plant disease resistance, efficient nutrient utilization and increasing plant growth. Processes such as nano encapsulation illustrate the advantages of more efficient use and safer handling of pesticides with less negative impacts on the environment hence ensuring eco protection [3].

Agricultural systems are losing their fertility because of human activities and societal change in lifestyle. This invariably affects the production of crops and could lead to famine and hunger, thus concerted efforts are necessary to improve plants to enhance production. Nanotechnology system serves as the newest system for modern agriculture, whereby methods are formulated and channeled towards meeting with food demands of the enhancing world population [4].

Urban cropping that makes use of recent nanotechnologies has the potential to contribute for food security and nutrition. Despite there are related risks from chemical polutions which may have released from soils, water [5], the ultimate goals for nanomaterials application in cropping spans decreasing hazard chemicals, nutrient losses, pest control and crop yield improvement [6]. The aim of this study was to investigate the use of nanotechnology in cropping systems and possibility of applying this technique for ameliorating desirable crop cultivation.

Background of Nanotechnology in cropping systems

The quest to apply nanotechnology in farming systems arises from the fact that population is constantly increases, which necessitates the need for more foods. Population survey has estimated about 9.5 billion by the end of 2050 [5, 6]. Nanoscience is a fast-emerging field with an emphasis on broad range synthesis and application of different nanomaterials. This field can serve as a panacea for several difficult problems in multidisciplinary fields such as pharmaceutical sciences, supramolecular chemistry and electrical engineering [7, 8]. Nanomaterials have been awarded considerable attention due to their structure and properties differing from those of atoms and molecules with respect to their bulk materials, thus possessing various potential applications [9]. Nanoparticle synthesis is generally carried out by various chemical methods, such as laser ablation, pyrolysis, chemical or physical vapor deposition, sol gel and lithography electro-deposition. However most of these methods are expensive, and/or require the use of toxic solvents [10].

Table 1

Some Nano fertilizers used nowadays globally [15]

Nanofertilizers	Constituents	Name of Manufacturer
Nano Ultra-Fertilizer (500) g	organic matter, 5.5%; Nitrogen, 10%; P_2O_5, 9%; K_2O, 14%; P_2O_5, 8%; K_2O, 14%; MgO, 3%	SMTET Eco-technologies Co., Ltd., Taiwan
Nano Calcium (Magic Green) (1) kg	$CaCO_3$, 77.9%; $MgCO_3$, 7.4%; SiO_2, 7.47%; K, 0.2%; Na, 0.03%; P., 0.02%; Fe, 7.4 ppm; Al_2O_3, 6.3 ppm; Sr, 804 ppm; sulfate, 278 ppm; Ba, 174 ppm; Mn,172 ppm; Zn, 10 ppm	AC International Network Co., Ltd., Germany
Nano Capsule	N, 0.5%; P_2O_5, 0.7%; K_2O, 3.9%; Ca, 2.0%; Mg, 0.2%; S, 0.8%; Fe, 2.0%; Mn, 0.004%; Cu, 0.007%; Zn, 0.004%	The Best International Network Co., Ltd., Thailand
Nano Micro Nutrient (EcoStar) (500) g	Zn, 6%; B, 2%; Cu, 1%; Fe, 6%+; EDTA Mo, 0.05%; Mn, 5%+; AMINOS, 5%	Shan Maw Myae Trading Co., Ltd., India
PPC Nano (120) mL	M protein, 19.6%; Na_2O, 0.3%; K_2O, 2.1%; $(NH_4)_2SO_4$, 1.7%; diluent, 76%	WAI International Development Co., Ltd., Malaysia
Nano Max NPK Fertilizer	Multiple organic acids chelated with major nutrients, amino acids, organic carbon, organic micronutrients / trace elements, vitamins, and probiotic	JU Agri Sciences Pvt. Ltd., Janakpuri, New Delhi, India
TAG NANO (NPK, PhoS, Zinc, Cal, etc.) fertilizers	Proteino-lacto-gluconate chelated with micronutrients, vitamins, probiotics, seaweed extracts, and humic acid	Tropical Agrosystem India (P) Ltd., India

Recently, great activities have been made to use environmentally sustainable methods for the nanoparticles synthesis [11]. This is largely obtained by the using plant or fruit extracts and bioorganisms [12, 13]. Using fertilizers is an age long practice and has tremendously increased crop yields. However, they lead to soil mineral imbalance, destroy the soil structure, soil fertility and general ecosystem, which are serious impediments in the long term. To deal with the situation, it is pertinent to develop smart materials that can release nutrients to targeted areas and contribute to clean environment. Recent researches have indicated that graphene is a promising material that could serve as a carrier for plant nutrients. It is capable of slow and controlled reveal of nutrient for the plants benefit, and eventually enhances the amount of production with low environmental impact [14, 5]. Some Nano fertilizers used in the world are shown in table 1.

Green synthesis of nanoparticles

Nanomaterials have nanoscale dimension, and nanoparticles are very small size particles with increased catalytic reactivity, thermal conductivity, non-linear optical performance and chemical steadiness owing to its large surface area to volume ratio. These compounds are the ones possibly responsible for the anti-pathological responses of plants [16]. Increase in new resistant strains of insects, bacteria and fungi against most potent antibiotics prompted researchers to conduct experiments on the activity of well-known compounds, including Nanoparticles and the resistance phenomenon was more pronounced against insect pests than other organisms.

Biosynthesis of nanoparticles is a strategy of synthesizing nanoparticles applying microorganisms having biomedical applications. Mentioned method is an environmental friendly and cost effective, biocompatible and safe approach. Green synthesis involves synthesis through plants, bacteria, fungi, algae etc. They allow large scale production of ZnO NPs free of additional impurities. NPs synthesized from biomimetic approach show more catalytic activity and limit the use of expensive and toxic chemicals [17—19].

Physical synthesis encompasses the sedimentation process, rotor speed ball mill, high energy ball mill and pot mill. For instance, phosphorus (P) nanoparticles are provided by purifying rock phosphate and grinding with high energy mill. Chemical approaches include precipitation and poly vinyl pyrimidine (PVP) techniques. The use of microorganisms as potential bio-factories for synthesis of metallic Nanoparticles such as cadmium sulphide, gold, and silver has been explored [20, 21].

Synthesis methods

Two strategies have been advised for synthesis of nanomaterials: 1) bottom up and 2) top down methods. The top-down strategy includes milling or attrition of large macroscopic particle. That includes synthesizing large scale patterns initially and then diminishing it to nanoscale level through plastic deformation. This strategy cannot be used for large scale production of nanoparticles, because of its high cost and slow process. This approach includes the nanoparticles synthesis from miniaturized atomic components through self-assembly [22]. That involves formation through physical and chemical means. Meanwhile, that is a cheap cost technique comparatively.

Nanoparticles and plant protection

Anthracnose disease, which is caused by *Colletotrichum* is a serious disease that appears on host plant and other cereal crops. For controlling various phytopathogenic fungi, including *Colletotrichum* species, agrochemical products have been advanced and applied for a long period of time. Widespread using fungicides has certainly diminished the outbreak of diseases, but simultaneously contributed to the development of resistant pathogen strains and biotypes [21, 22]. Anthracnose disease, which is caused by the fungal pathogen *Colletotrichum* is a devastating disease that occurs on many commercially important plants like bean, strawberry, perilla and other crop plants [23]. In order to control various phytopathogenic fungi, including *Colletotrichum* species, agrochemicals have been used for a long time. Widespread use of agrochemicals has certainly decreased the outbreak of fungal diseases, but at the same time has contributed to the development of resistant pathogens. Moreover, such chemicals can be lethal to beneficial organisms.

Nanomaterials have been observed as novel antimicrobial agents owing to their high surface area to volume ratio and the unique chemical and physical characteristics, that increase their contact with microbes and ability to permeate cells [24]. Nano science has shown the impact of silver particles as antimicrobial agents. Shrinking the particle size of materials is very effective point to ameliorate their biological compatibility.

The existence of fungal phytopathogens during the development of host plant is essential as mentioned organisms can induce wilt or root rot disease causing substantial losses to crop producers. Currently, pathogenic fungi such as *Fusarium solani* and *Macrophomina phaseolina* have been recognized in some crops in various countries such as Spain and Iran as the causal agent of crown rot, root rot and charcoal rot, respectively [25]. Pastrana et al. [4] reported that these pathogens caused root rot, damping-off symptoms, and shrinking in leaf size and fruits, thus affecting the yield and quality. Several researches reported the use of various control measures such as the application of chemical and biological tools for curbing these diseases in crops. Currently environmental hazards caused by the using fungicides and the unpredictable results of biological control have been comprehensively discussed [26].

Nanotechnology and abiotic stresses

Improvement in the plant resistance against different abiotic stresses such as drought, salinity, diseases and others have been possible through development in the biotechnology science at the nanomaterials or nanoscale. In the future, more useful identification and use of plant gene trait resources is expected to introduce cost effective capability through advances in nanotechnology based on gene sequencing [27]. Latterly, in vitro culture has become widely used in some research areas related to plant science, owing to its ability to provide quick feedback, virus-free and controlled environment [28]. The use of nanomaterials has recently increased in agriculture and plant-tissue culture thanks to their unique different properties such as: magnetic, electrical, mechanical, optical, and chemical properties. Mozafari et al. [29] reported that under in vitro conditions, the use of iron nanoparticle could effectively alleviate the negative effects of drought stress on strawberry, further they verified that the concentration of iron nanoparticle could be an important issue worthy of consideration while adjusting the micronutrient content of media for this plant.

Nano-fertilizers in cropping systems

Nano-fertilizers might have new properties which are more effective in farming systems, controlled release of chemical fertilizers and release nutrients that regulate plant growth and increase target activity. Nano-fertilizers can increase crop yields by supplying one or more nutrients whereas nanomaterial-increased fertilizers ameliorate the performance of fertilizers. Nano-fertilizers compared with the conventional fertilizers, are expected to improve growth and yields of crops significantly [30].

Recently several researchers stated that Nanofertilizers affected the seed germination which showed the effect of Nanofertilizers on seed. They can easily penetrate into the seed and increase nutrient availability to the growing seedling which results in healthy growth. If concentration is more than the optimum it may indicate inhibitory effects on the germination and seedling growth of the plant. Nano particles have both positive and negative effects on the plant [31].

ZnO Nano-particles recorded higher peanut seed germination percentage and root growth in comparison with bulk zinc sulphate. In the same way, positive effects of Nano-scale SiO_2 and TiO_2 on germination were reported in soya bean. Appropriate seed germination and root length were observed when using nanofertilizers compared to control where seeds were not treated with Nano-fertilizer. Nano-fertilizers increase nutrient availability to the growing plant which increases chlorophyll formation, photosynthetic rate, and dry matter production resulting in improvement of overall plant growth. Mozafari et al. [32] reported corresponding results that nano-TiO_2 treated seeds produced plants with more dry weight, higher photosynthetic rate, and chlorophyll-α formation compared to the control. Combining Nanofertilizers and nanodevices synchronizing the release of fertilizers N and P with their uptake by cereal crop, prevents undesirable nutrient losses to soil through direct internalization by crops [33].

Conclusion

Nano Science has appropriate advantages as it can enhance the life quality through its usage in various aspects as in cropping systems and producing foods. Across the globe it has become a ticket into the future for most nations. Nevertheless, we must be very careful with any new technology to be introduced about its possible unforeseen related risks that may come along with its positive potential. It is critical for any nation to provide a trained future workforce well versed in nanotechnology. Nanoparticle production has obtained well attention from various researchers those wish to utilize them for developing new generation nano-agro fertilizers and pesticides. Nanotechnology development is generating interests in science towards ecofriendly, cost effective and biological synthesis of nanoparticles.

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Обзорная статья

Роль нанотехнологий в совершенствовании растениеводства

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Аннотация. Использование наноматериалов в последнее время возросло в сельском хозяйстве и культуре тканей растений благодаря их уникальным свойствам: магнитным, электрическим, механическим, оптическим и химическим. Приведен обзор исследований, посвященных применению нанотехнологий в растениеводстве, подтверждающих в частности, что наноматериалы усиливают рост растений, повышают сопротивляемость болезням и устойчивость растений, предотвращая изгиб и обеспечивая более глубокое укоренение сельскохозяйственных культур, а оптимальное использование железа, например, увеличивает содержание белка в зерне пшеницы. Многие исследователи сообщают, что наноудобрения значительно повлияли на всхожесть семян, что продемонстрировало влияние наноудобрений на семена и их энергию. Отмечено, что для синтеза наночастиц используются химические методы, а развитие нанобиотехнологии вызывает интерес к исследованиям, направленным на экологически чистый, экономически эффективный биологический синтез наночастиц. Сегодня зеленые нанотехнологии обеспечивают различные способы воздействия на патогенные микроорганизмы: грибы и многие виды бактерий. Показано применение систем наночастиц в практике борьбы с грибковыми заболеваниями растений, использование их в качестве биосенсоров в диагностике заболеваний растений.

Ключевые слова: наночастица, наноудобрение, нанотехнология

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